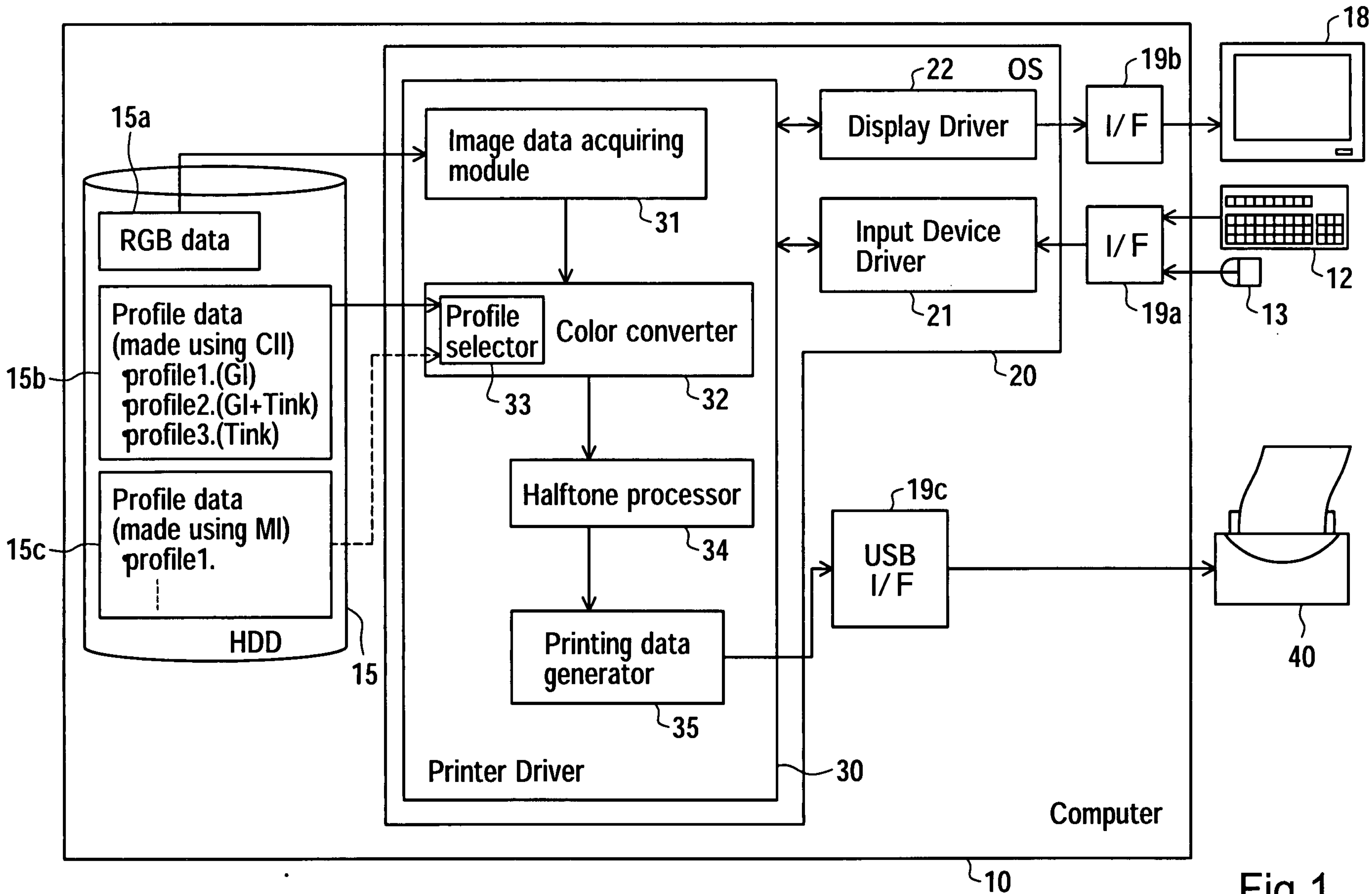


18
19b
22
OS
Display Driver
I/ F
Input Device Driver
I/ F
12
21
19a
13
20
15a
Image data acquiring module
31
RGB data
Profile data
(made using CII)
profile1.(GI)
profile2.(GI+Tink)
profile3.(Tink)
Profile selector
Color converter
15b
33
32
Halftone processor
34
Profile data
(made using MI)
profile1.
15c
19c
USB I/ F
HDD
15
Printing data generator
35
40
Printer Driver
30
Computer
10

Fig.1

PF04J641

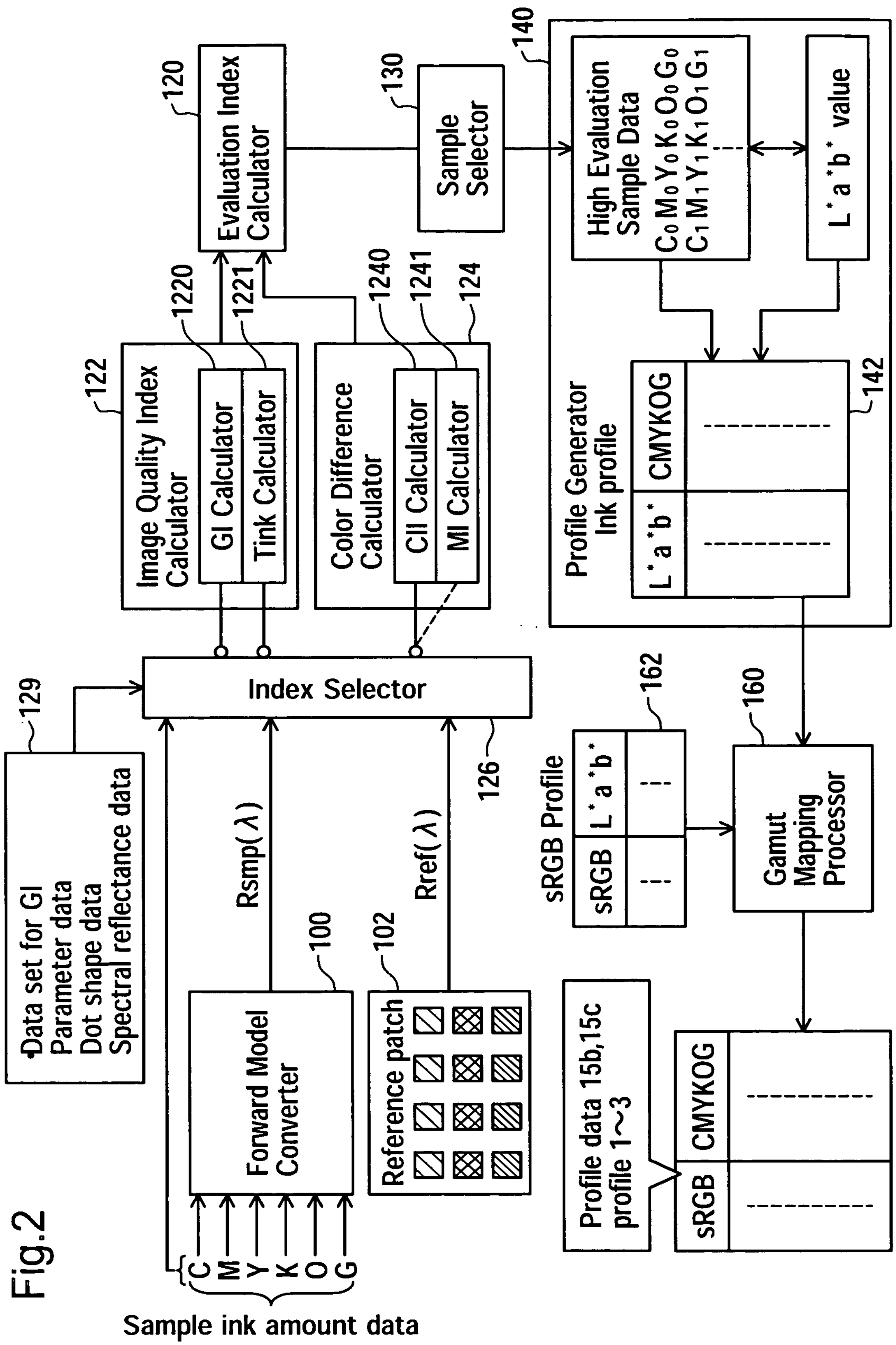


Fig.2

Fig.3

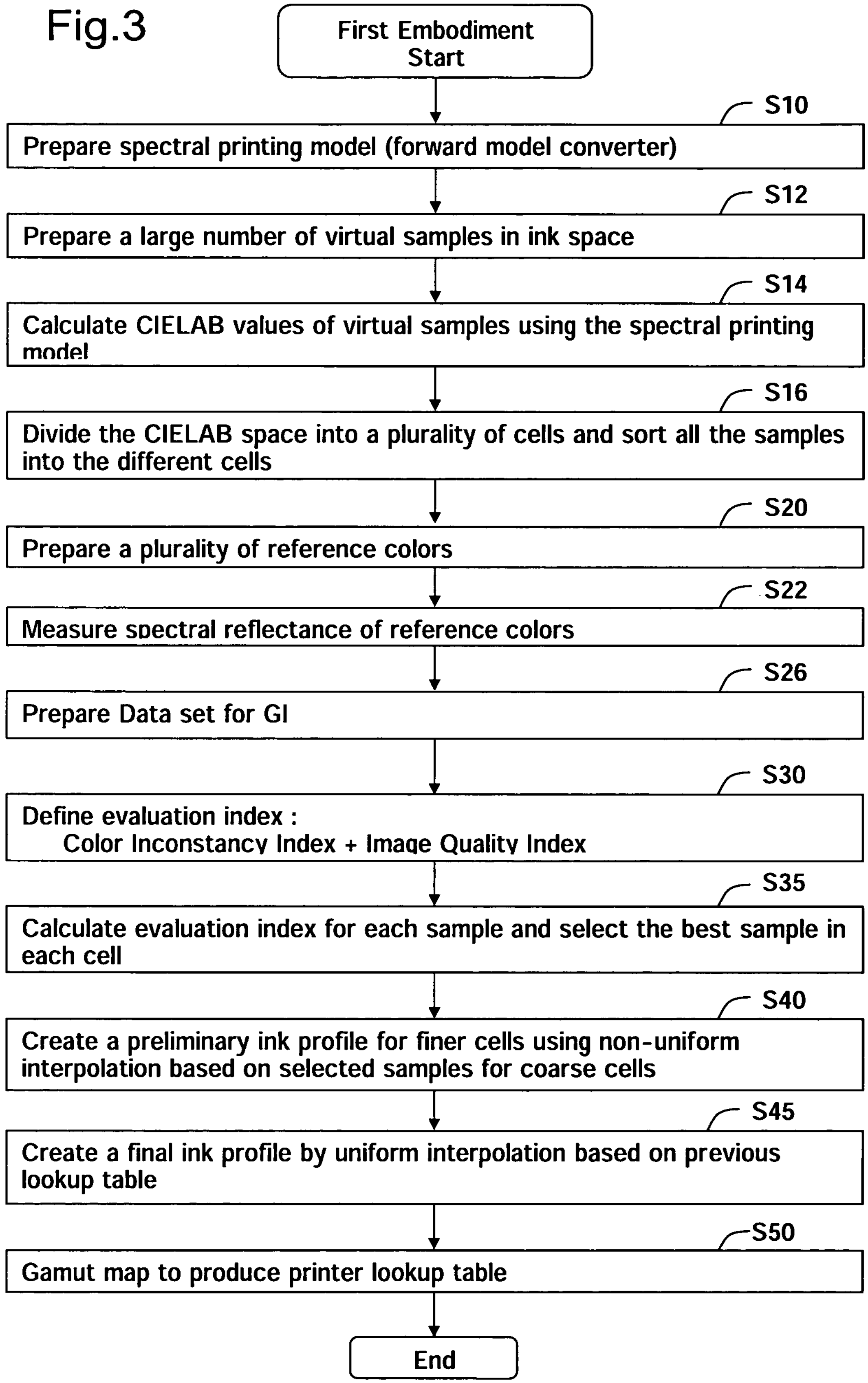

First Embodiment Start
S10
Prepare spectral printing model (forward model converter)
S12
Prepare a large number of virtual samples in ink space
S14
Calculate CIELAB values of virtual samples using the spectral printing model
S16
Divide the CIELAB space into a plurality of cells and sort all the samples into the different cells
S20
Prepare a plurality of reference colors
S22
Measure spectral reflectance of reference colors
S26
Prepare Data set for GI
S30
Define evaluation index : Color Inconstancy Index + Image Quality Index
S35
Calculate evaluation index for each sample and select the best sample in each cell
S40
Create a preliminary ink profile for finer cells using non-uniform interpolation based on selected samples for coarse cells
S45
Create a final ink profile by uniform interpolation based on previous lookup table
S50
Gamut map to produce printer lookup table
End

Fig. 4(A)

Fig. 4(B)

Fig. 4(C)

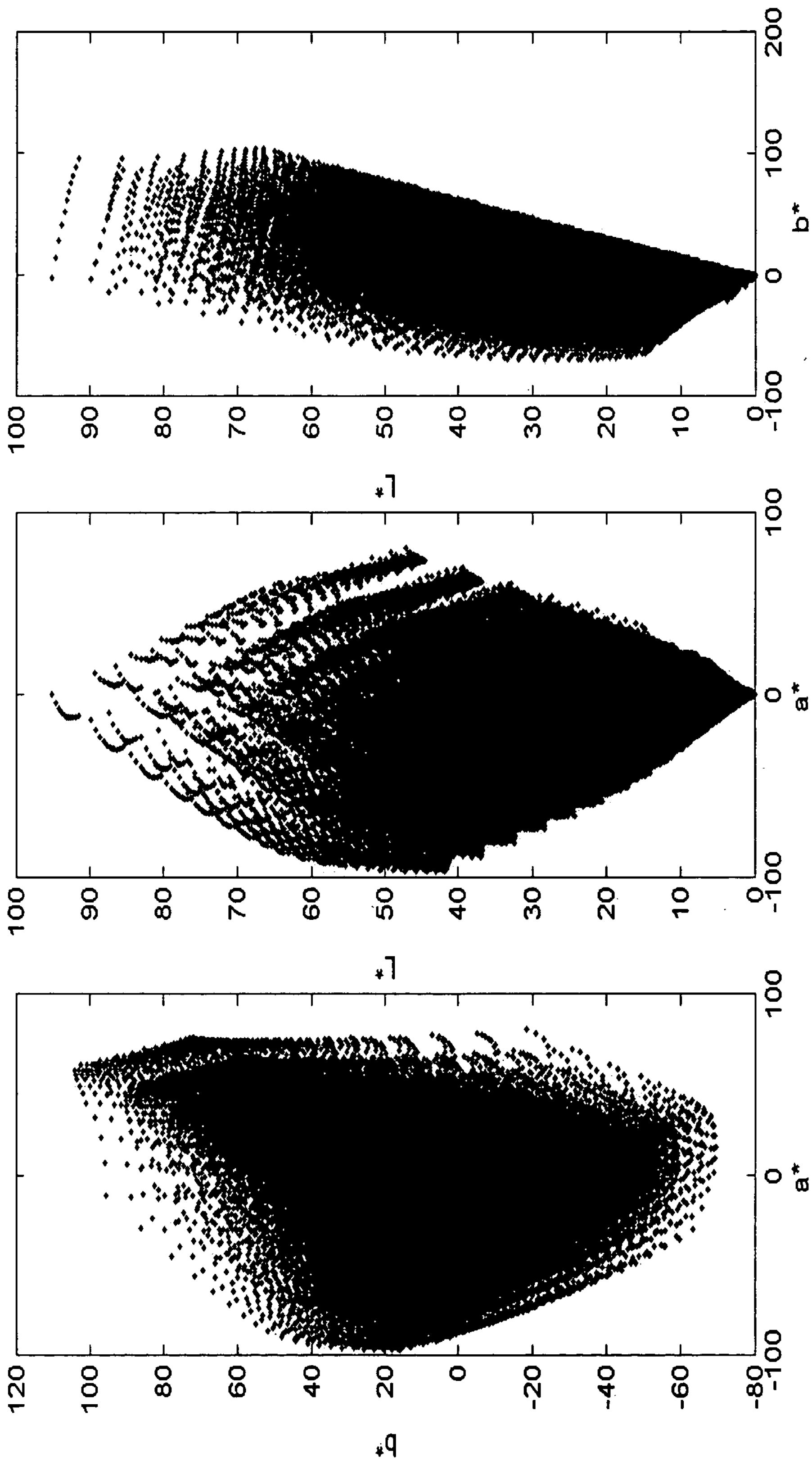


Fig.5

parameter data

• X resolution	: 1440dpi
• Y resolution	: 720dpi
• number of colors	: 6
• printing media	: photo paper
• number of subpixels／pixel	: 20
• number of nozzles	: 180

Fig.6

dot shape data

		first dot		second dot		relative distance	
color	nozzle No	Xsize (Y_0)	Ysize (Y_0)	Xsize (X_1)	Ysize (Y_1)	Xsize (X_2)	Ysize (Y_2)
C	#1 #180	46 42	24 22	0 0	0 0	0 0	0 0
M	#1 #180						
Y	#1 #180						
K	#1 #180						
O	#1 #180						
G	#1 #180						

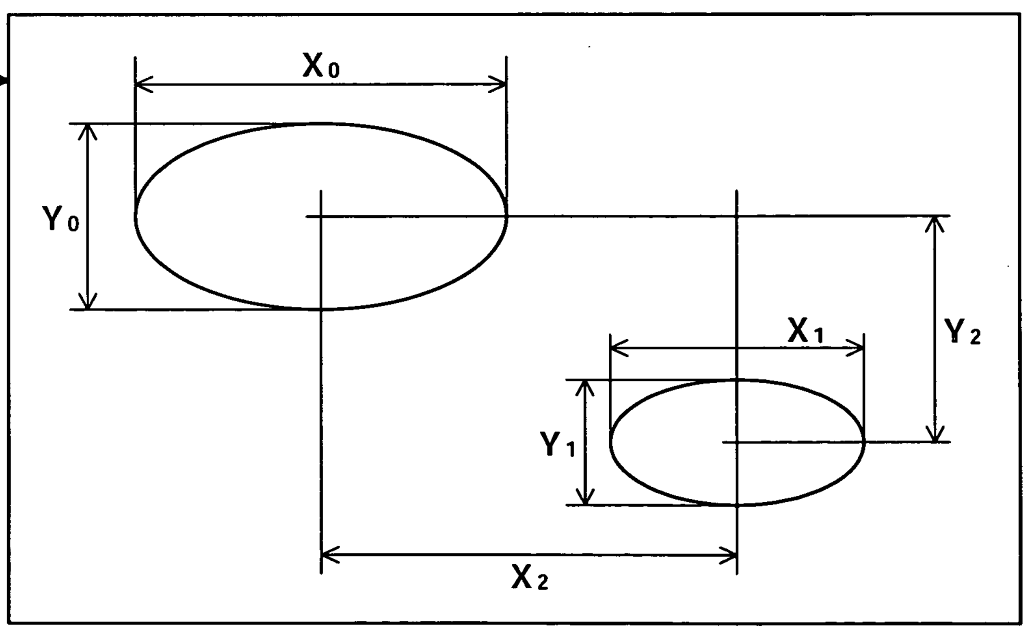
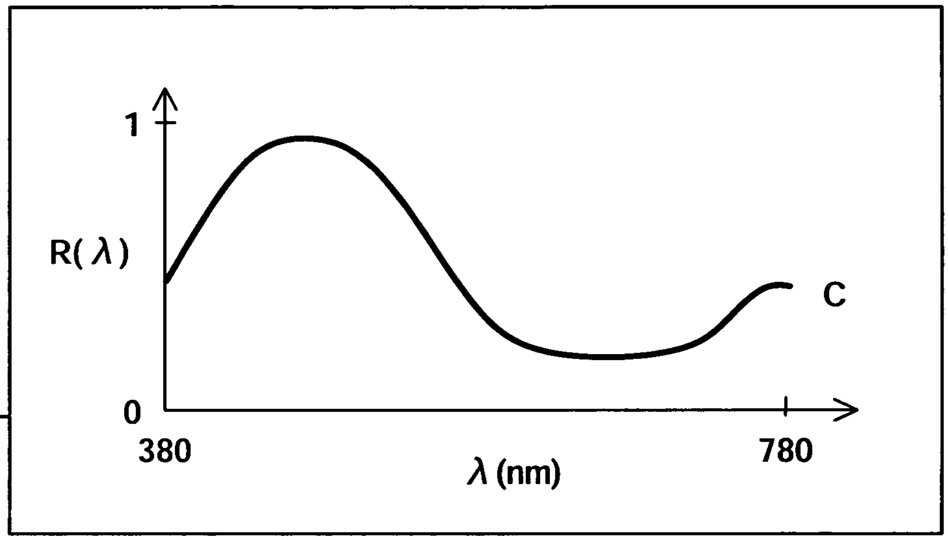


Fig.7



spectral reflectance data

λ	380	390	400	------------	780
C	0.21	0.25	0.384	------------	
M					
Y					
K					
O					
G					
W					

Fig.8

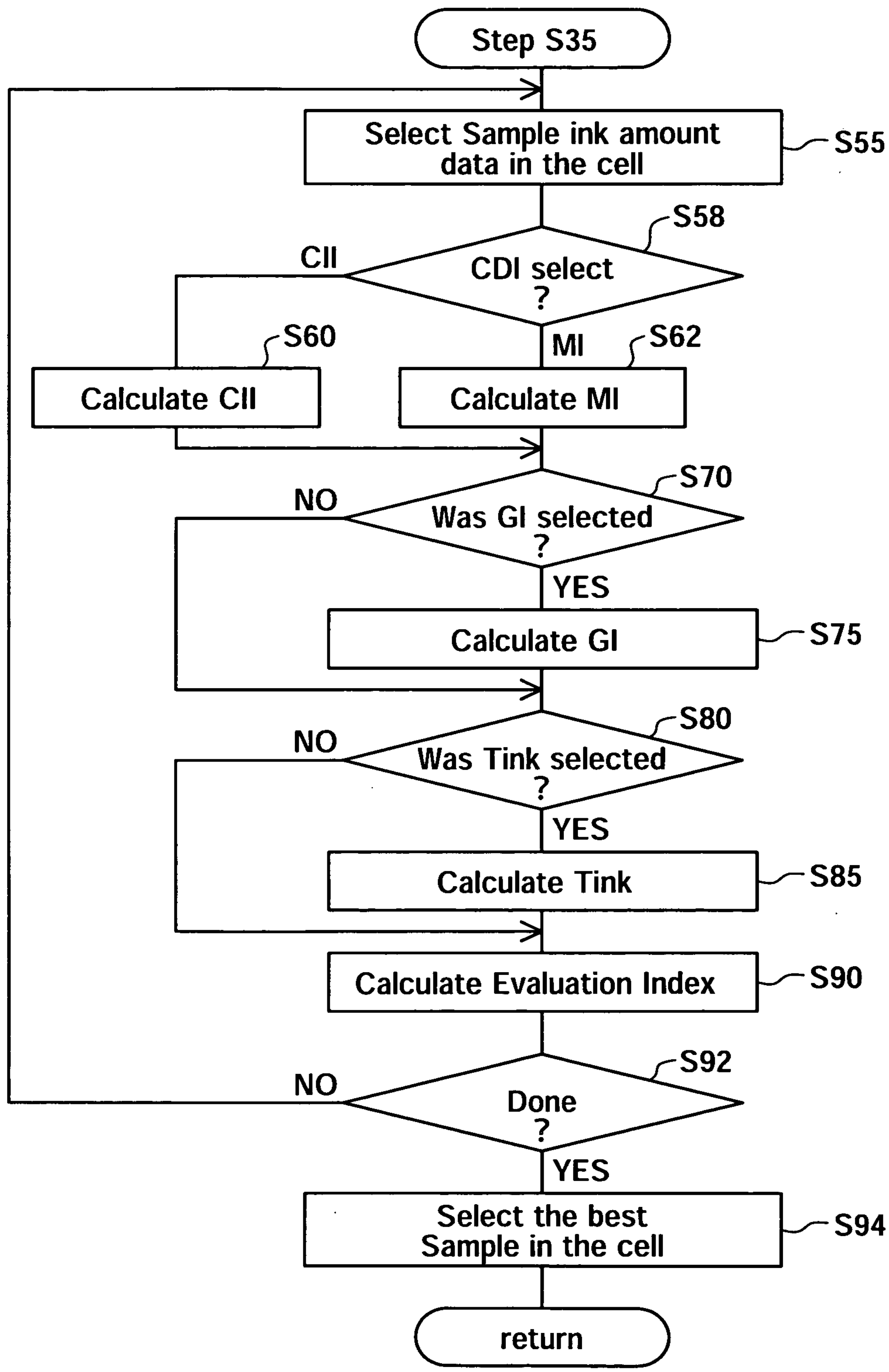

Step S35
Select Sample ink amount data in the cell
S55
S58
CDI select ?
CII
MI
S60
S62
Calculate CII
Calculate MI
S70
Was GI selected ?
NO
YES
Calculate GI
S75
S80
Was Tink selected ?
NO
YES
Calculate Tink
S85
Calculate Evaluation Index
S90
S92
Done ?
NO
YES
Select the best Sample in the cell
S94
return

Fig.9

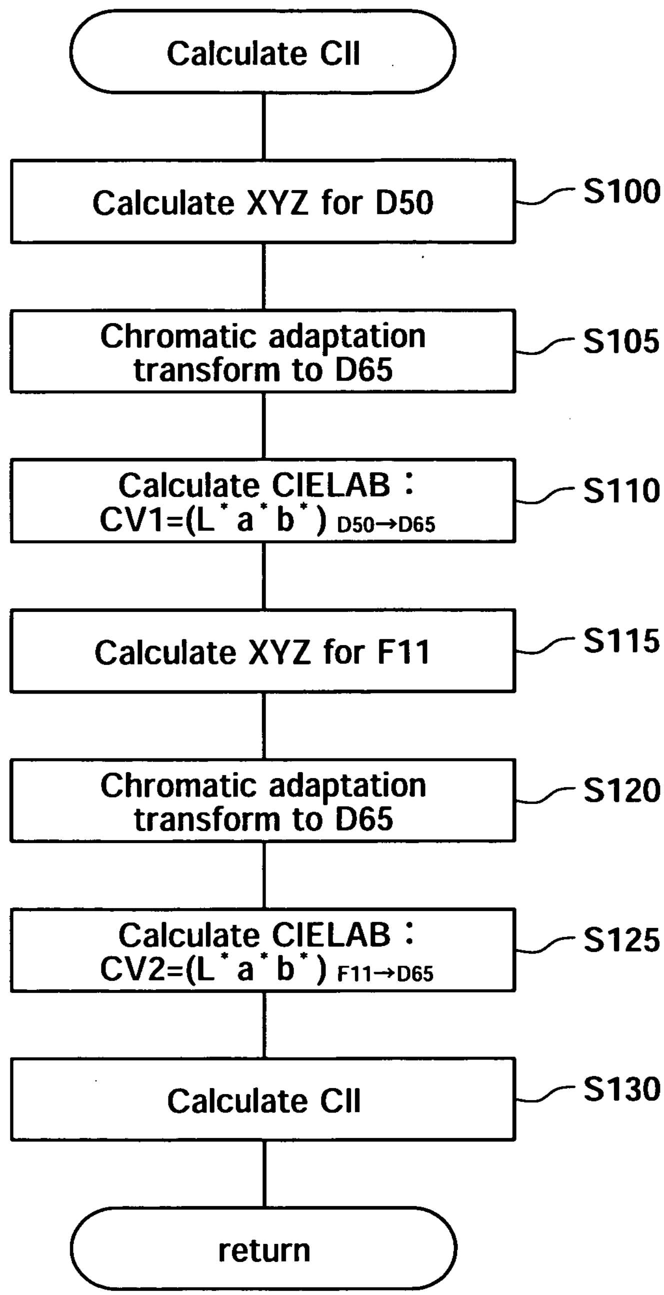

Calculate CII
Calculate XYZ for D50
S100
Chromatic adaptation transform to D65
S105
Calculate CIELAB : CV1=(L* a* b*) D50→D65
S110
Calculate XYZ for F11
S115
Chromatic adaptation transform to D65
S120
Calculate CIELAB : CV2=(L* a* b*) F11→D65
S125
Calculate CII
S130
return

Fig.10

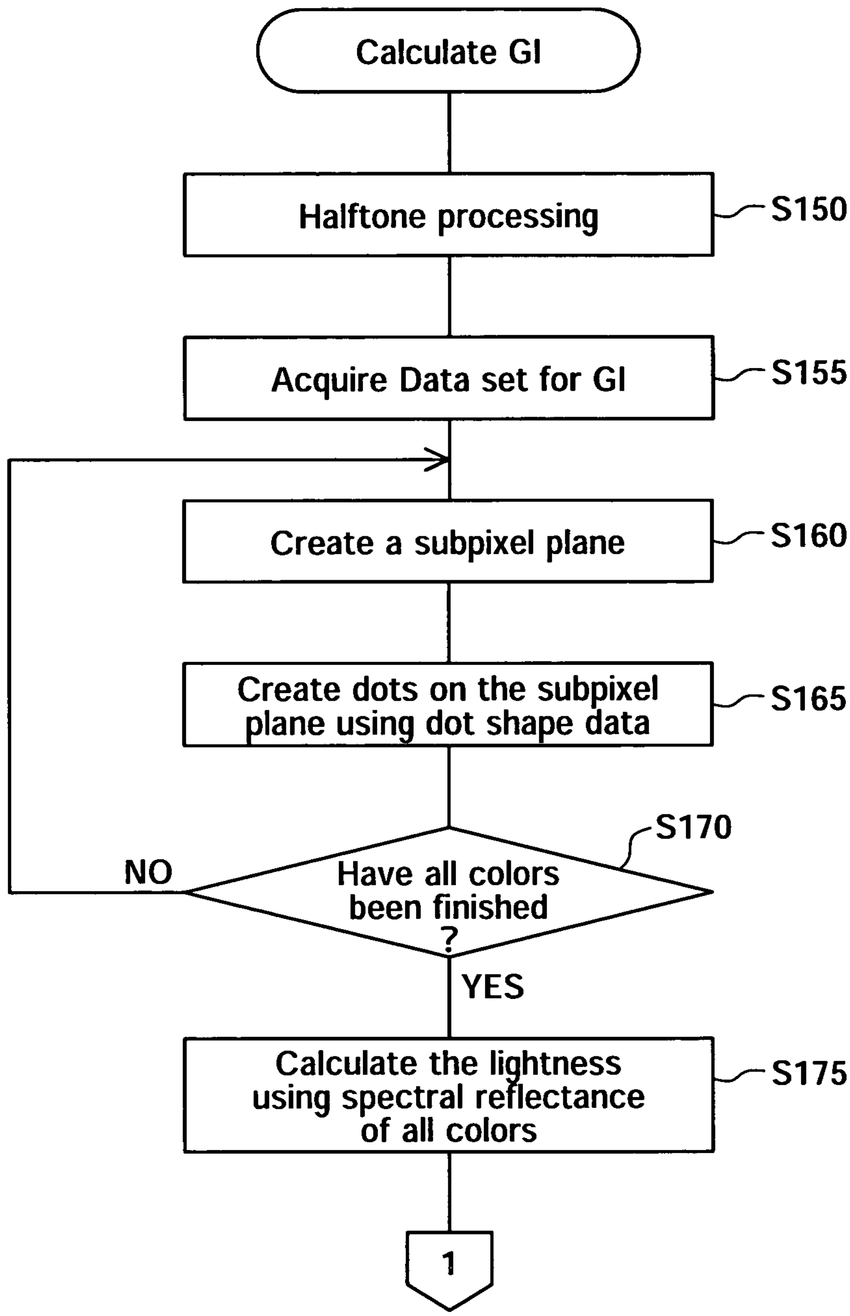

Calculate GI
Halftone processing
S150
Acquire Data set for GI
S155
Create a subpixel plane
S160
Create dots on the subpixel plane using dot shape data
S165
Have all colors been finished ?
S170
NO
YES
Calculate the lightness using spectral reflectance of all colors
S175
1

Fig.11

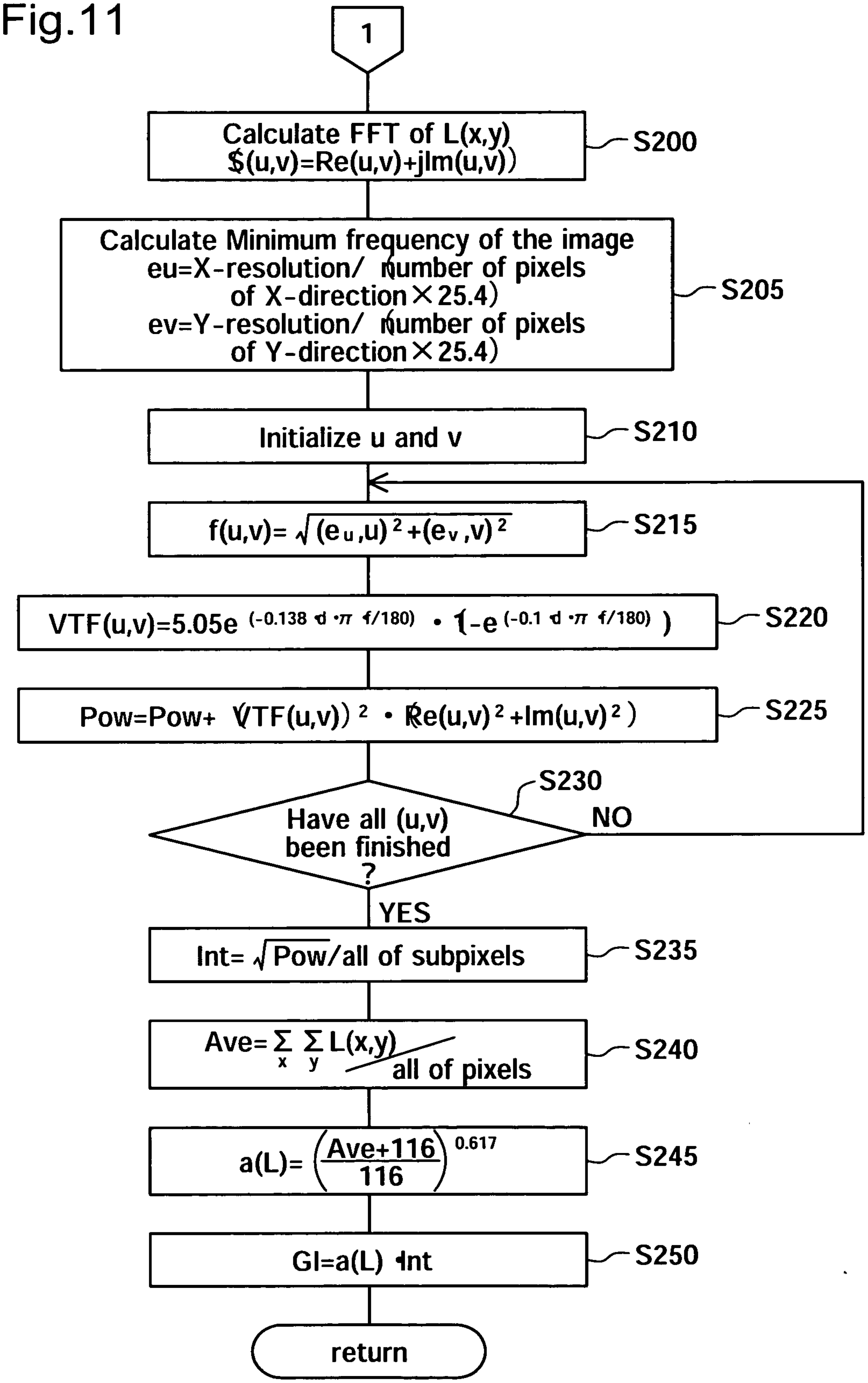
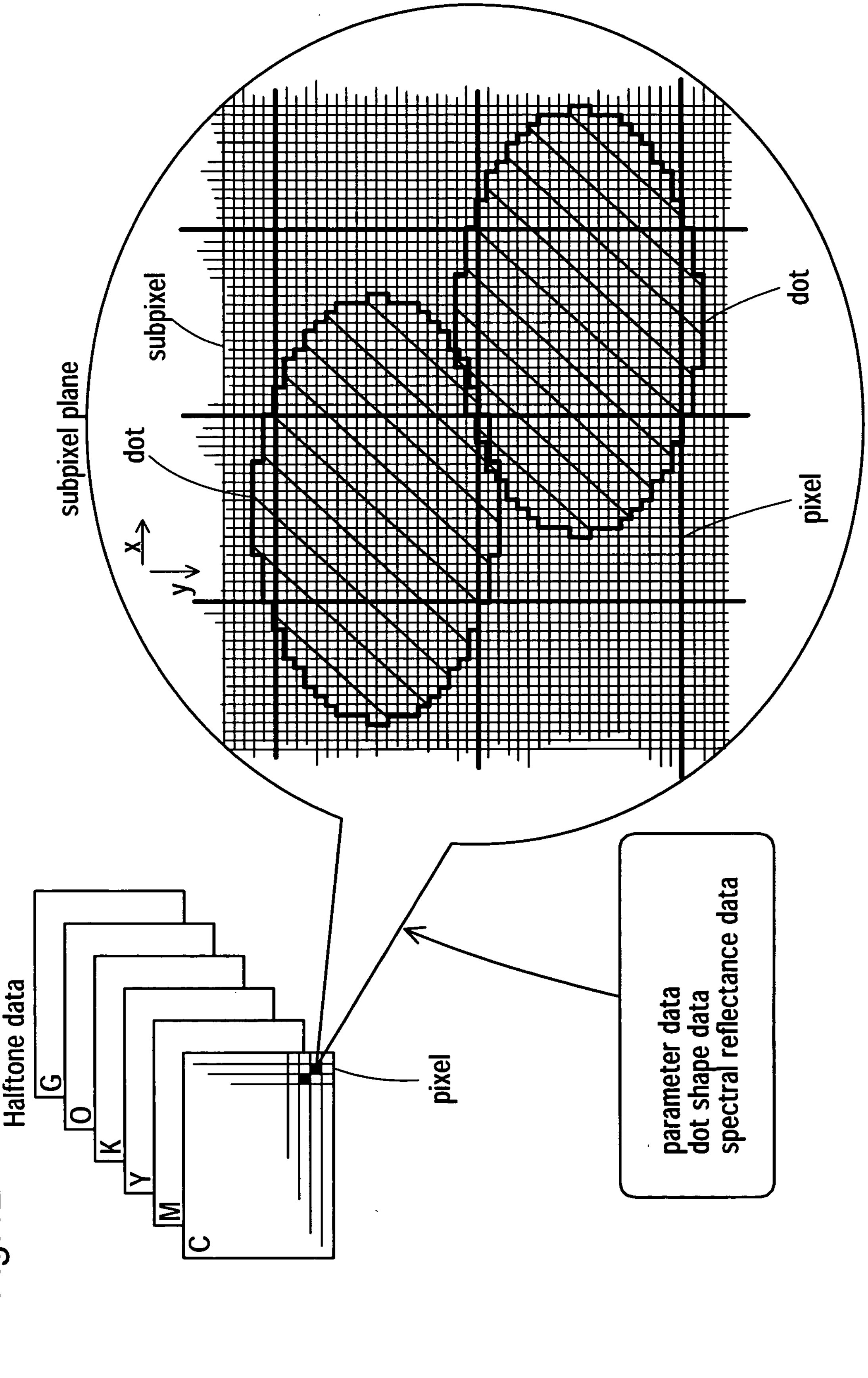

1
Calculate FFT of L(x,y)
S(u,v)=Re(u,v)+jIm(u,v))
S200
Calculate Minimum frequency of the image
eu=X-resolution/ (number of pixels
of X-direction×25.4)
ev=Y-resolution/ (number of pixels
of Y-direction×25.4)
S205
Initialize u and v
S210
f(u,v)= √(eu,u)²+(ev,v)²
S215
VTF(u,v)=5.05e (-0.138·d·π·f/180) · (1-e (-0.1·d·π·f/180))
S220
Pow=Pow+ (VTF(u,v))² · (Re(u,v)²+Im(u,v)²)
S225
S230
Have all (u,v)
been finished
?
NO
YES
Int= √Pow/all of subpixels
S235
Ave=Σx Σy L(x,y)/all of pixels
S240
a(L)= ((Ave+116)/116)^0.617
S245
GI=a(L)·Int
S250
return

Fig.12


Halftone data
G
O
K
Y
M
C
pixel
subpixel plane
subpixel
dot
x
y
dot
pixel
parameter data
dot shape data
spectral reflectance data

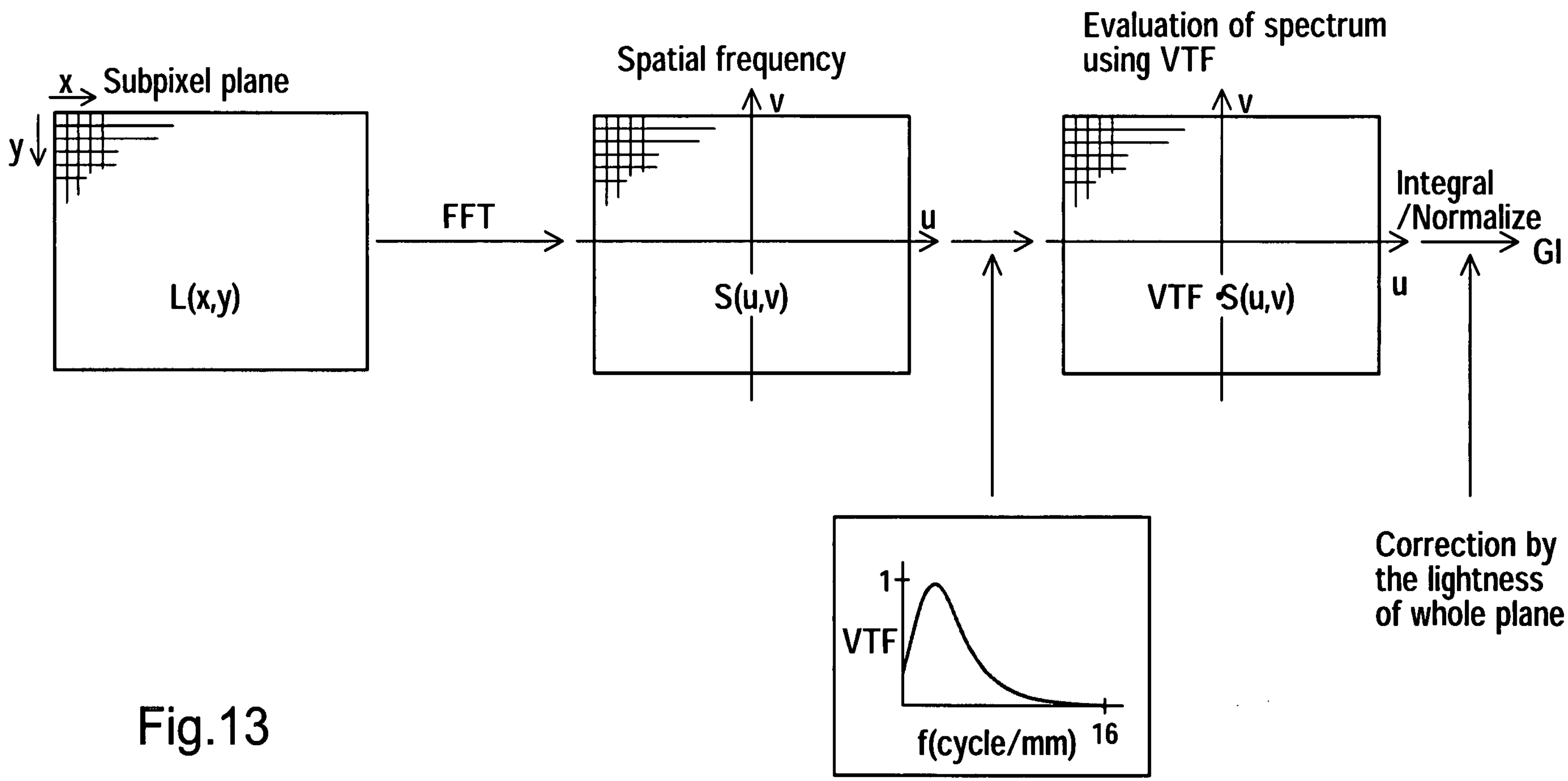

Subpixel plane
x
y
L(x,y)
FFT
Spatial frequency
v
u
S(u,v)
Evaluation of spectrum
using VTF
VTF •S(u,v)
Integral
/Normalize
GI
1
VTF
f(cycle/mm)
16
Correction by
the lightness
of whole plane

Fig.13

Fig.14(A)

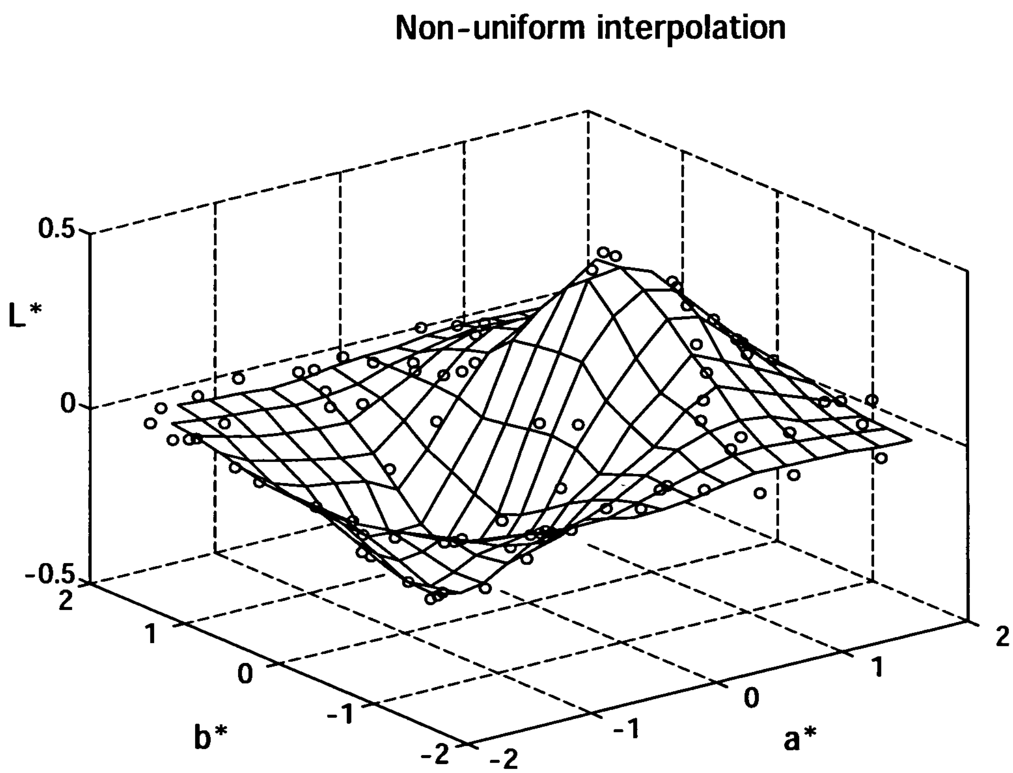


Fig.14(B)

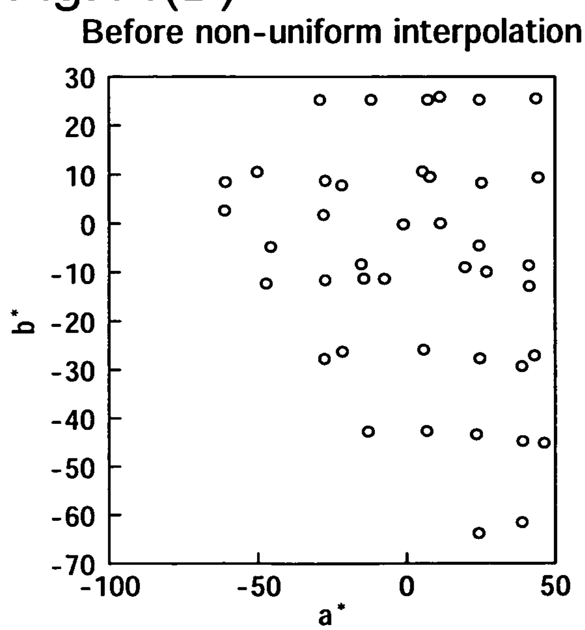


Fig.14(C)

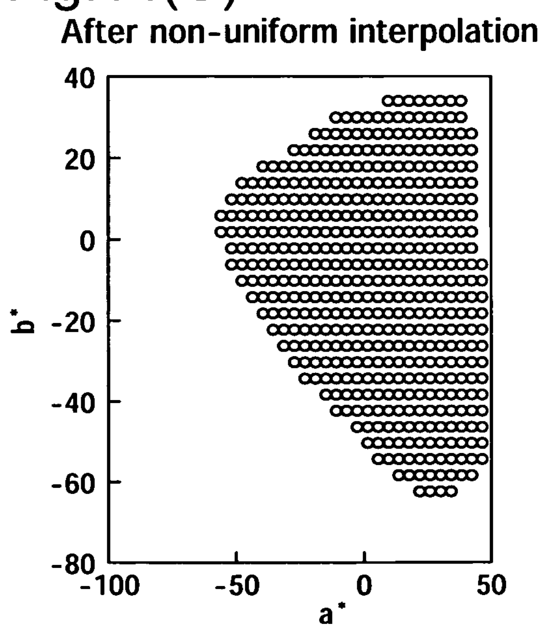


Fig. 15(A)

Gamut Mapping

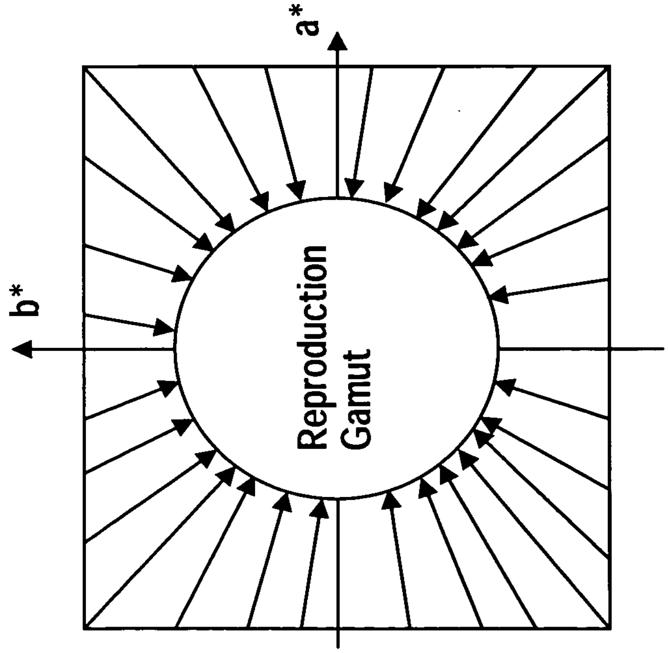


Fig. 15(B)

Gamut Mapping

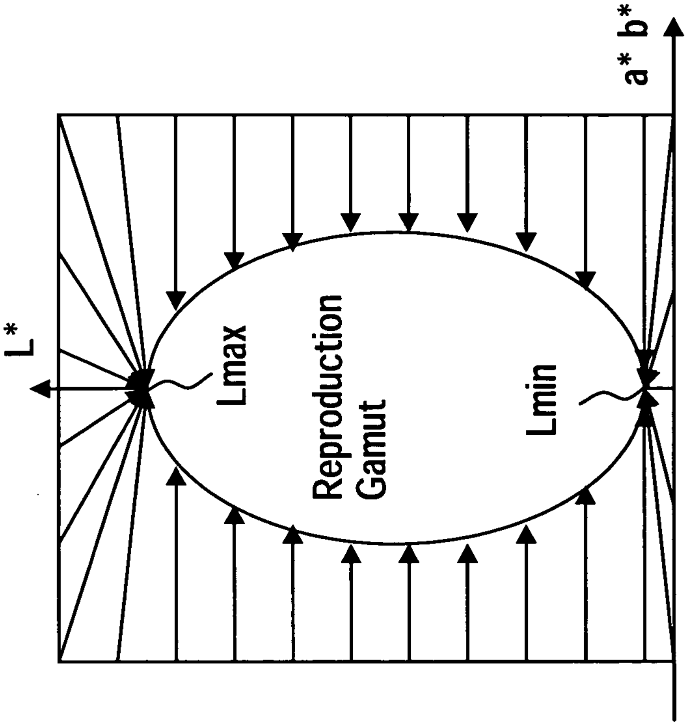
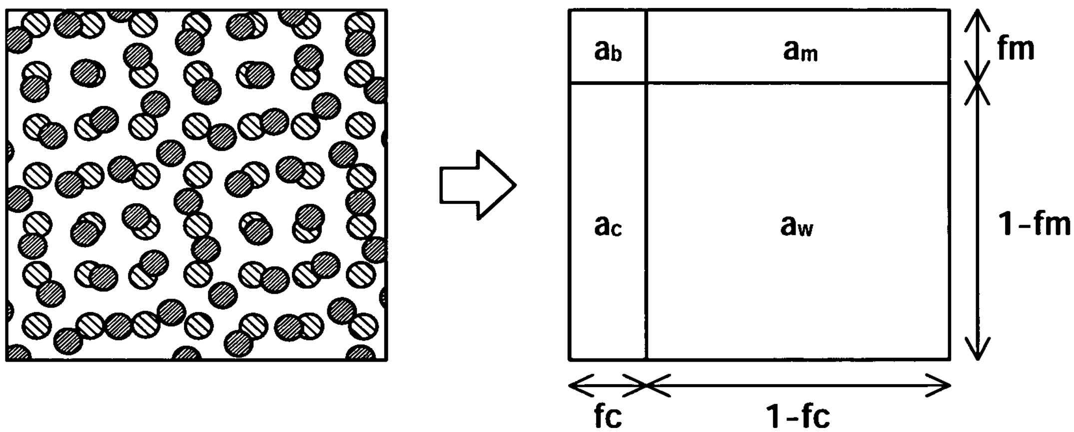


Fig.16(A)

Spectral Neugebauer model

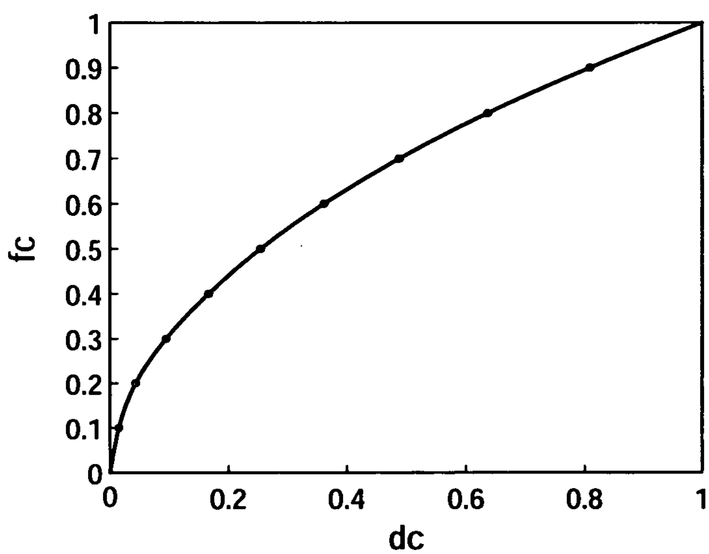


$$R(\lambda)=a_w R_w(\lambda)+a_c R_c(\lambda)+\cdots+a_k R_k(\lambda)$$

$$a_w=(1-f_c)(1-f_m)(1-f_y)$$
$$a_c=f_c(1-f_m)(1-f_y)$$
$$a_m=(1-f_c)f_m(1-f_y)$$
$$a_y=(1-f_c)(1-f_m)f_y$$
$$a_r=(1-f_c)f_m f_y$$
$$a_g=f_c(1-f_m)f_y$$
$$a_b=f_c f_m(1-f_y)$$
$$a_k=f_c f_m f_y$$

Fig.16(B)

Murray-Davies model



$$f_c=f_{1D\text{-}LUT}(d_c)$$

Fig.17(A)

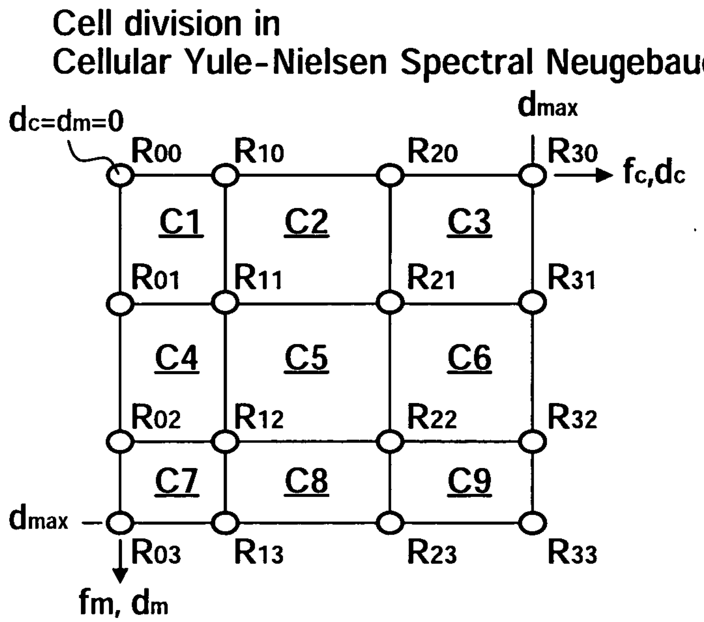


Fig.17(B)

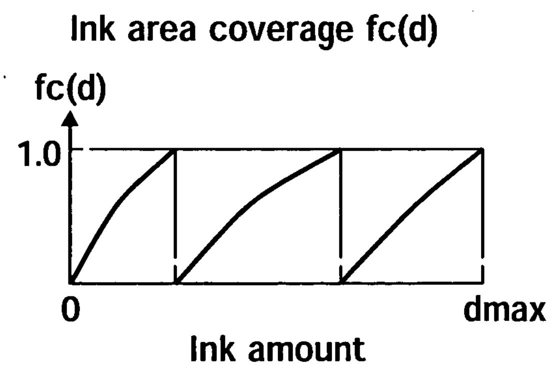
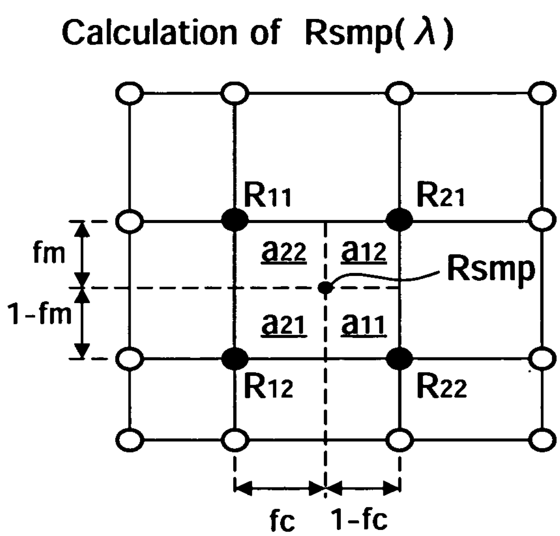


Fig.17(C)



$$Rsmp(\lambda) = \left(\sum a_i R_i(\lambda)^{1/n}\right)^n$$

$$= \left(a_{11}R_{11}(\lambda)^{1/n} + a_{12}R_{12}(\lambda)^{1/n} + a_{21}R_{21}(\lambda)^{1/n} + a_{22}R_{22}(\lambda)^{1/n}\right)^n$$

$$a_{11} = (1 - f_c)(1 - f_m)$$

$$a_{12} = (1 - f_c)\,f_m$$

$$a_{21} = f_c\,(1 - f_m)$$

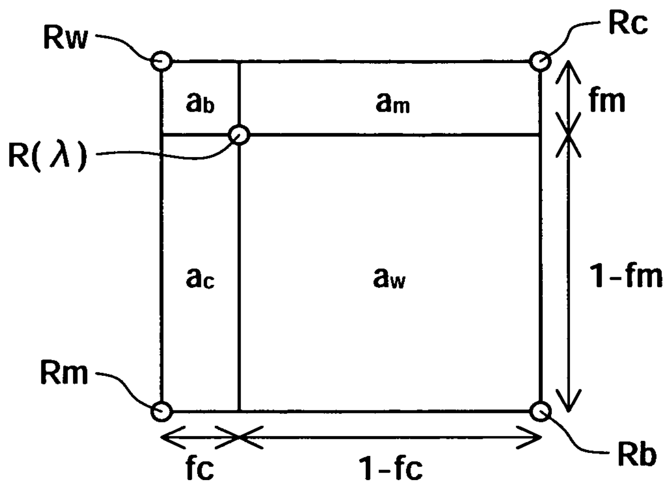
$$a_{22} = f_c\,f_m$$

Fig.18

Selected digital counts and area coverages of every ink for Cellular Yule-Nielsen Spectral Neugebauer Model

	Digital counts of ink amount			
Cyan	0	50	168	255
Magenta	0	56	173	255
Yellow	0	49	162	255
Black	0	56	126	255
Green	0	43	182	255
Orange	0	64	186	255

Fig.19



$$R(\lambda)=\{a_w R_w(\lambda)^{1/n}+a_c R_c(\lambda)^{1/n}+a_m R_m(\lambda)^{1/n}+a_b R_b(\lambda)^{1/n}\}^n$$

$$a_w=(1-f_c)(1-f_m)$$
$$a_c=f_c(1-f_m)$$
$$a_m=(1-f_c)f_m$$
$$a_b=f_c f_m$$

Smoothing Process

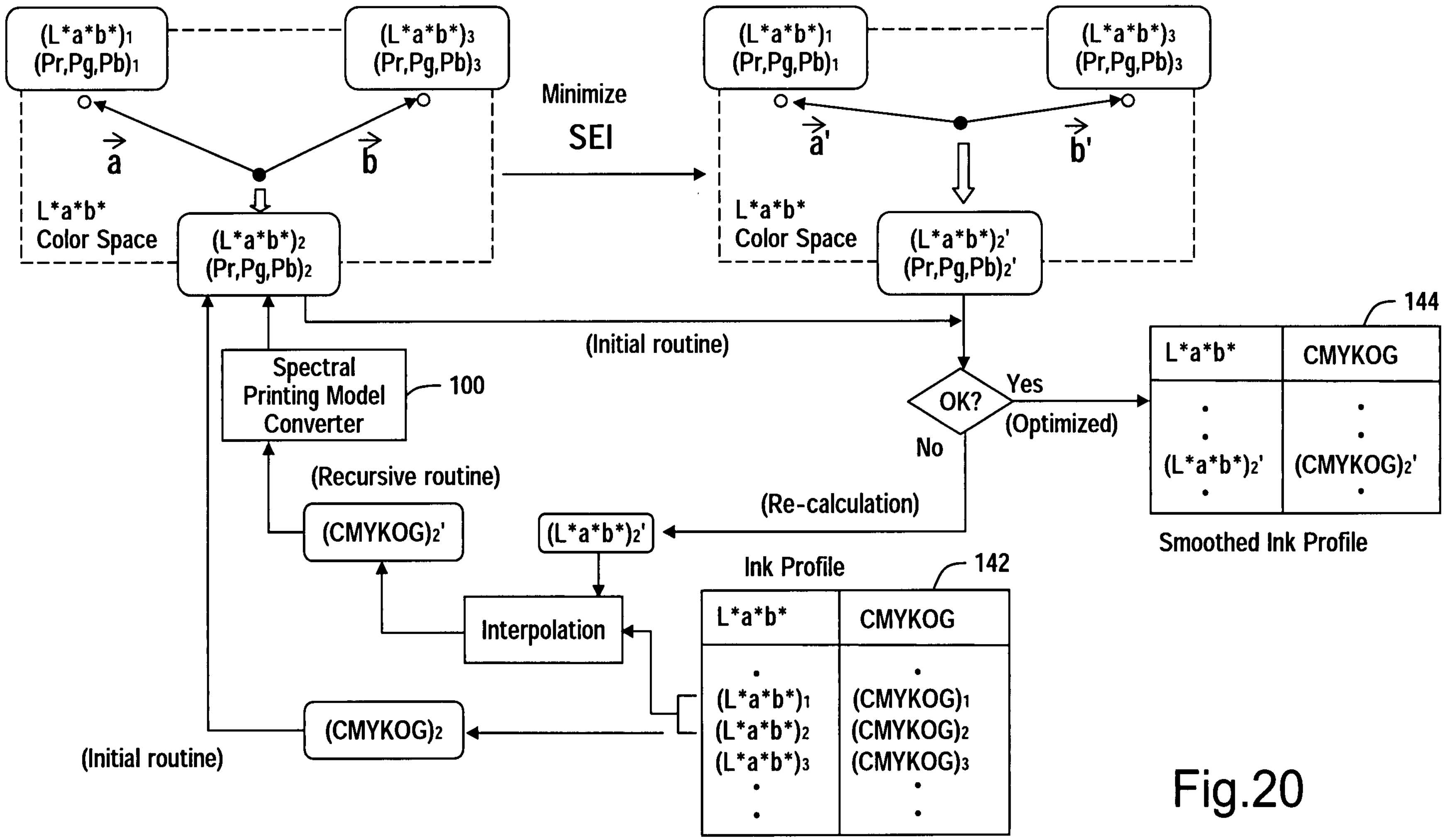
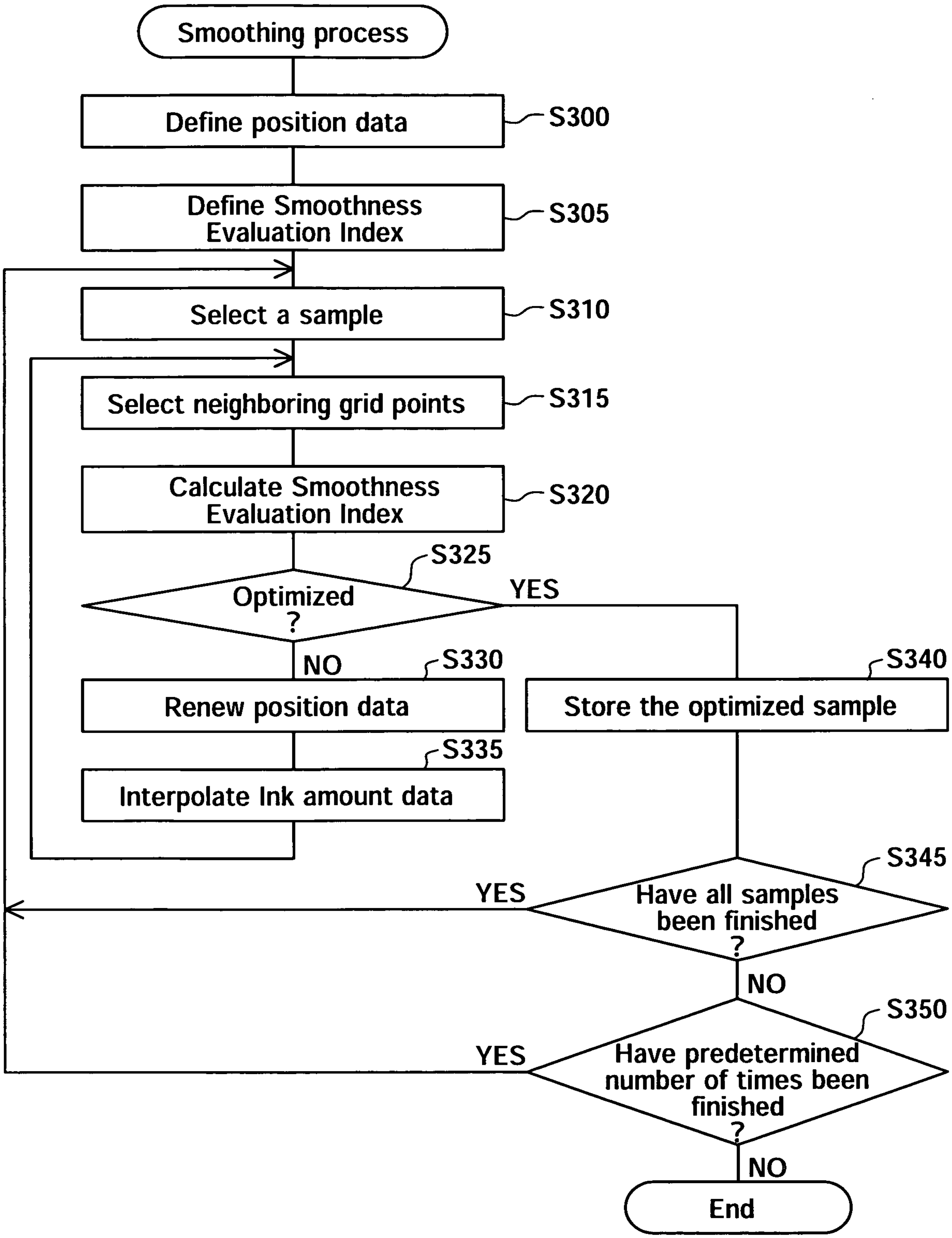


Fig.20

PF04J641

Fig.21



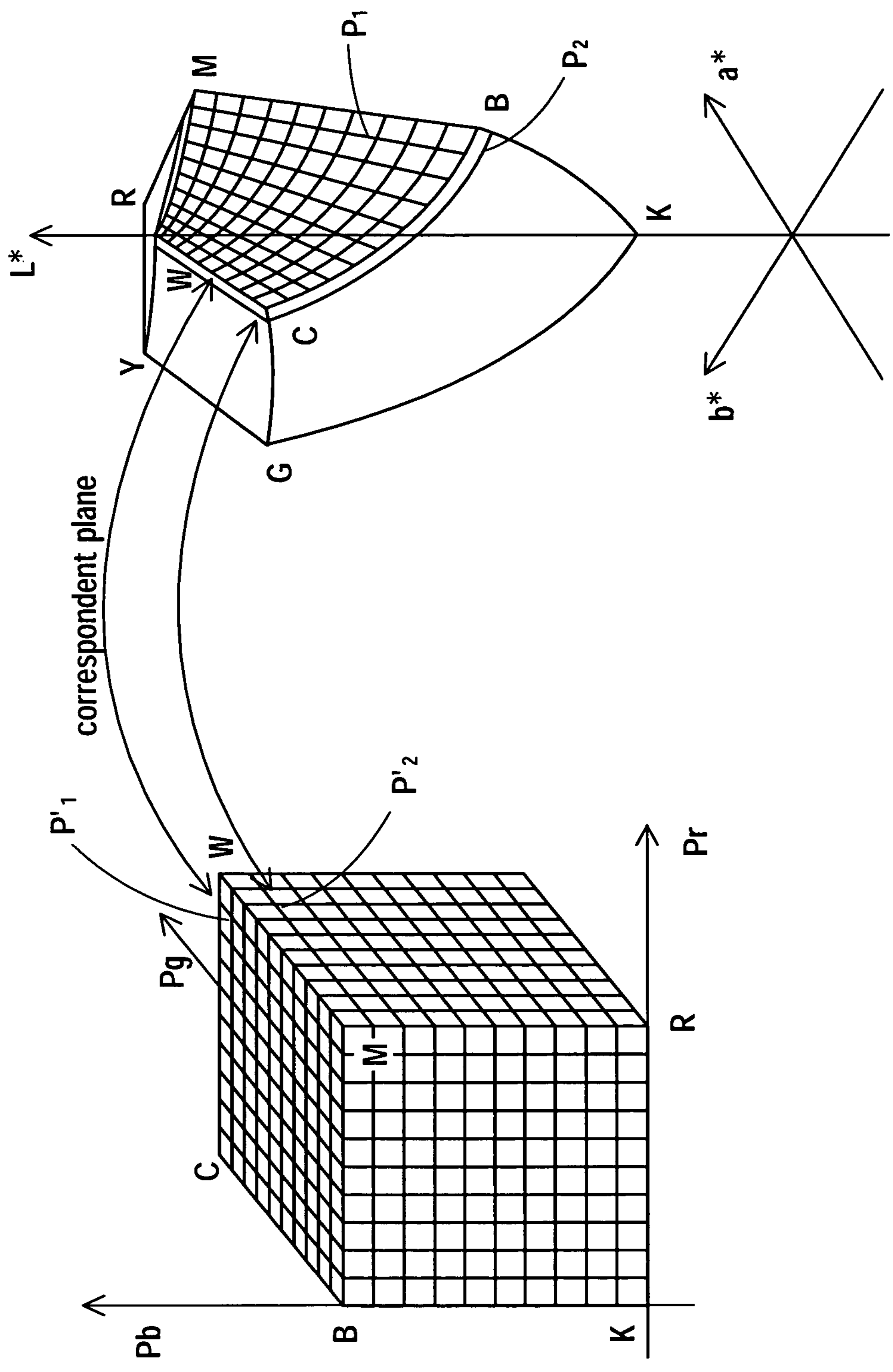


Fig.22

Fig.23

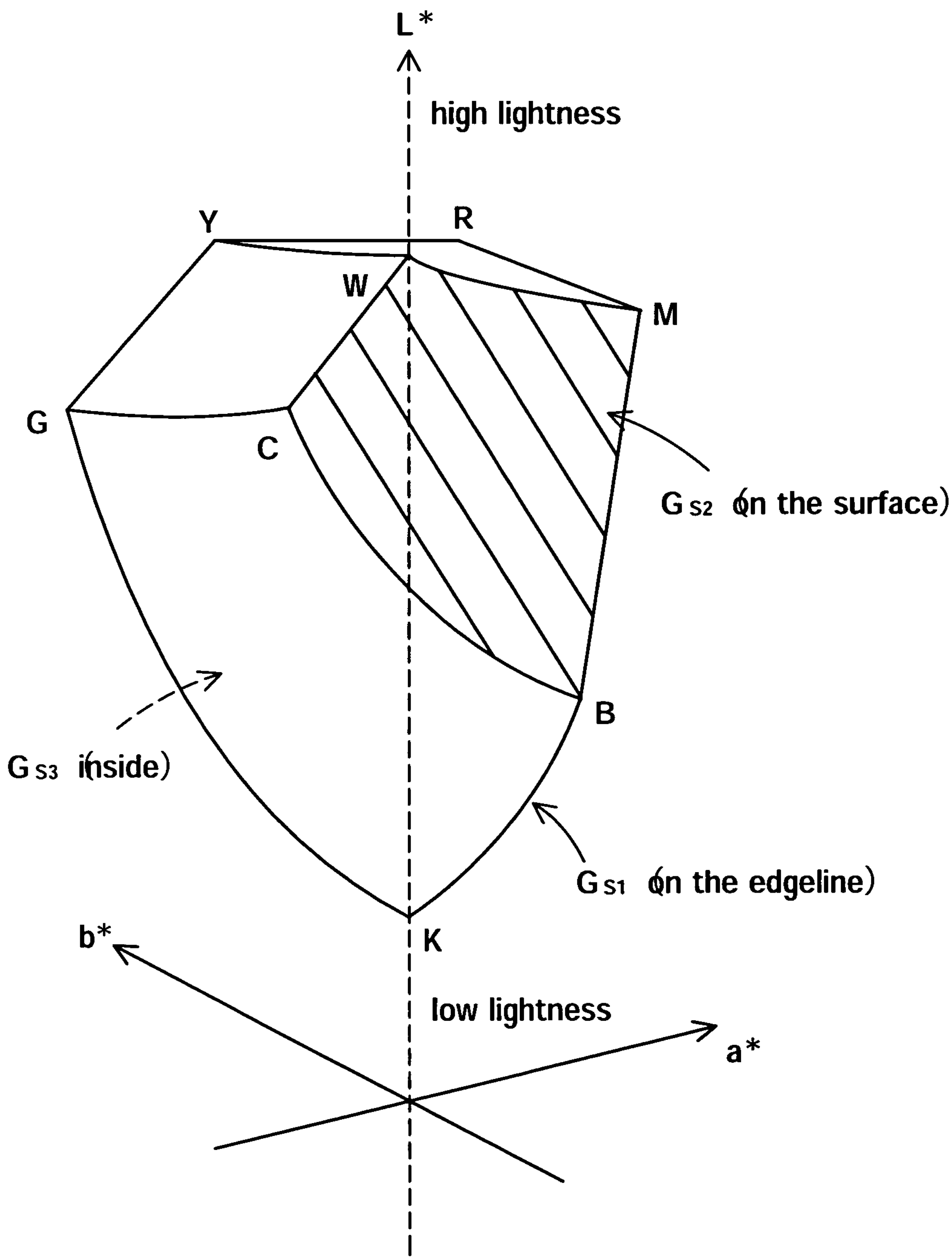

L*
high lightness
Y
R
W
M
G
C
G S2 (on the surface)
B
G S3 (inside)
G S1 (on the edgeline)
b*
K
low lightness
a*

Fig.24

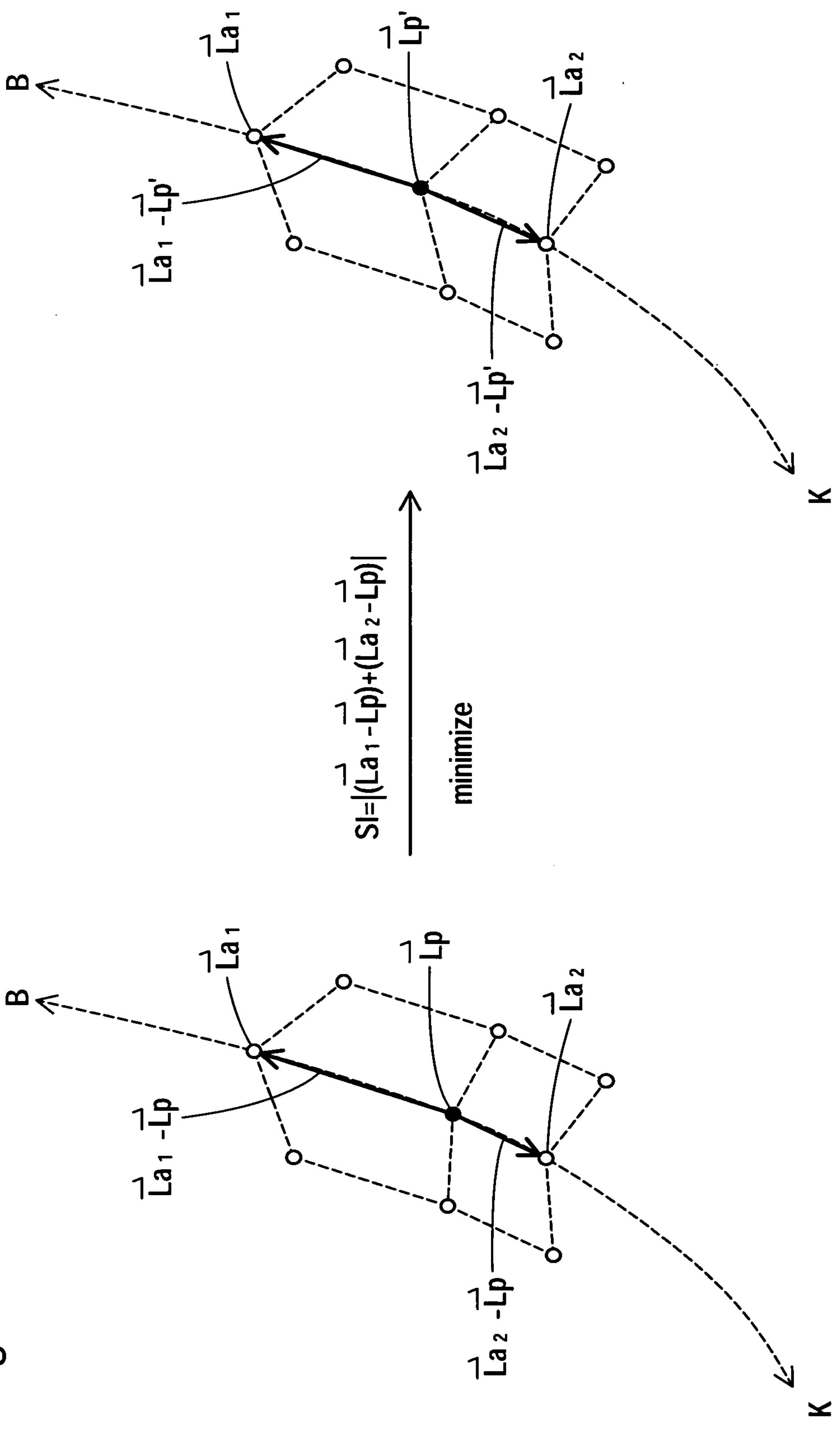
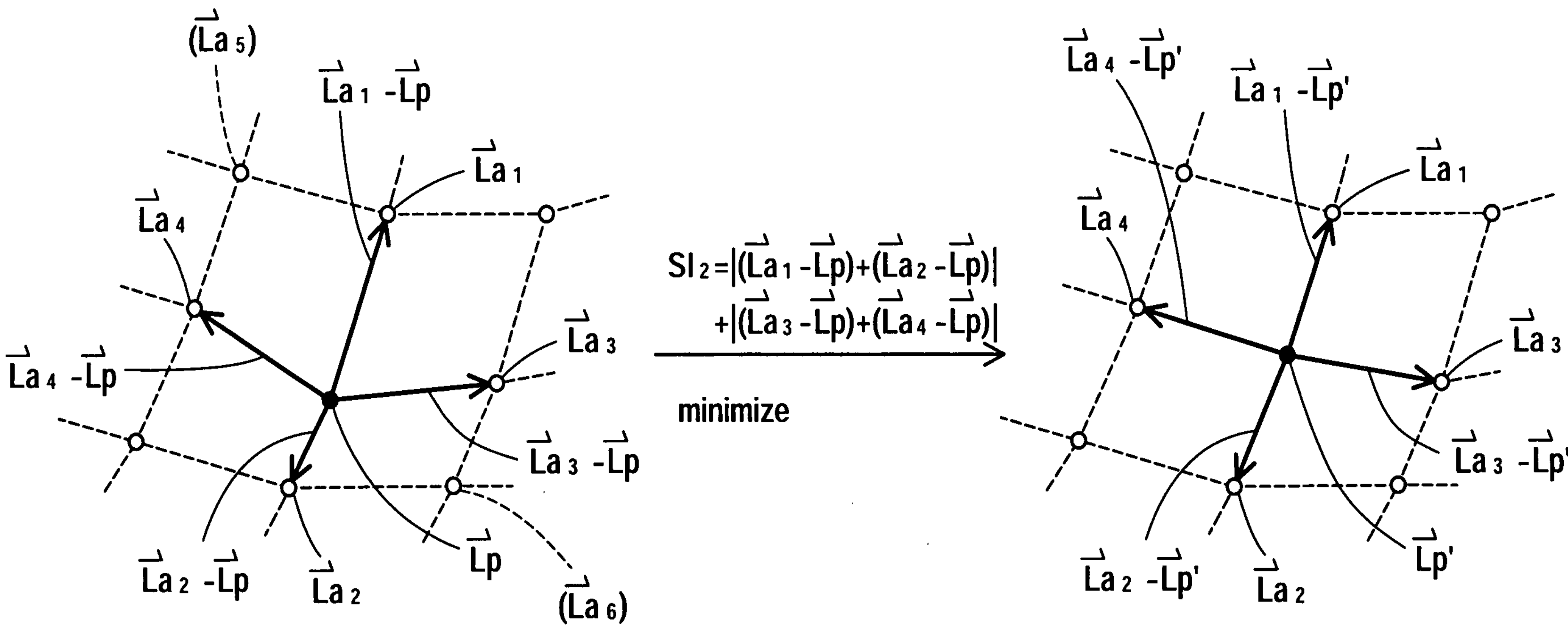

B
La1
Lp
La2
La1 -Lp
La2 -Lp
K
SI=|(La1 -Lp)+(La2 -Lp)|
minimize
B
La1
Lp'
La2
La1 -Lp'
La2 -Lp'
K

Fig.25



$(\vec{La}_5)$
$\vec{La}_1 - \vec{Lp}$
$\vec{La}_1$
$\vec{La}_4$
$\vec{La}_4 - \vec{Lp}$
$\vec{La}_3$
$\vec{La}_3 - \vec{Lp}$
$\vec{La}_2 - \vec{Lp}$
$\vec{La}_2$
$\vec{Lp}$
$(\vec{La}_6)$
$SI_2 = |(\vec{La}_1 - \vec{Lp}) + (\vec{La}_2 - \vec{Lp})| + |(\vec{La}_3 - \vec{Lp}) + (\vec{La}_4 - \vec{Lp})|$
minimize
$\vec{La}_4 - \vec{Lp}'$
$\vec{La}_1 - \vec{Lp}'$
$\vec{La}_1$
$\vec{La}_4$
$\vec{La}_3$
$\vec{La}_3 - \vec{Lp}'$
$\vec{La}_2 - \vec{Lp}'$
$\vec{La}_2$
$\vec{Lp}'$

Fig.26

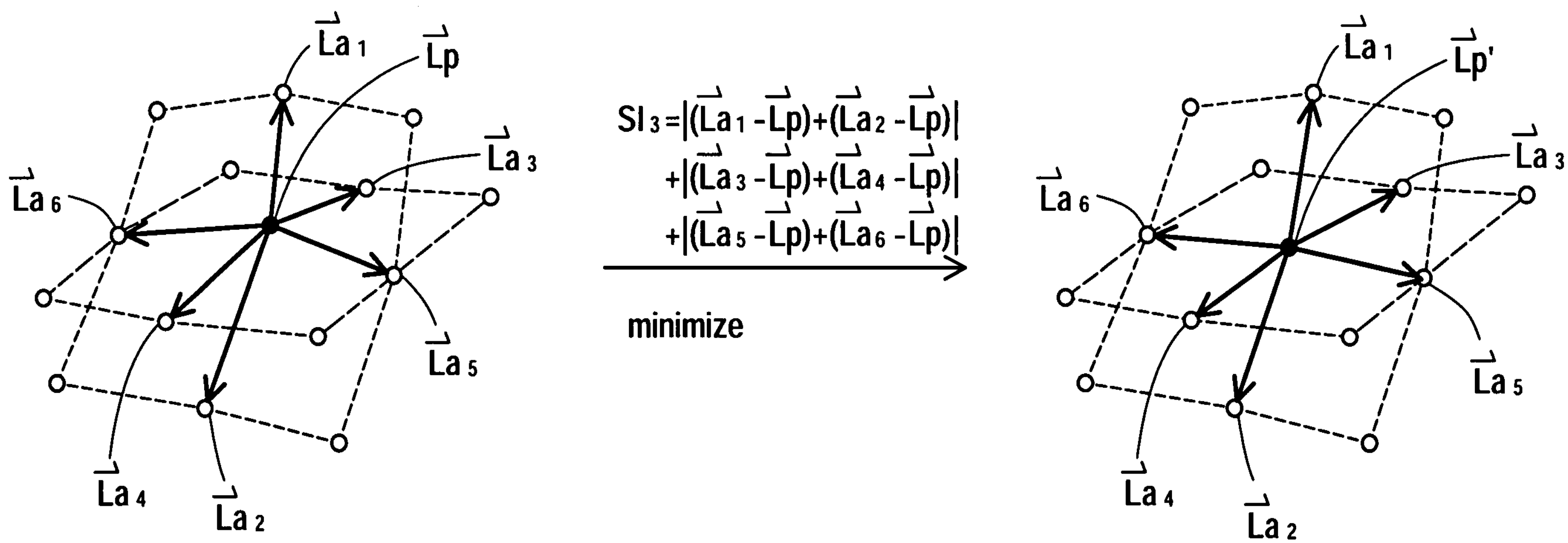
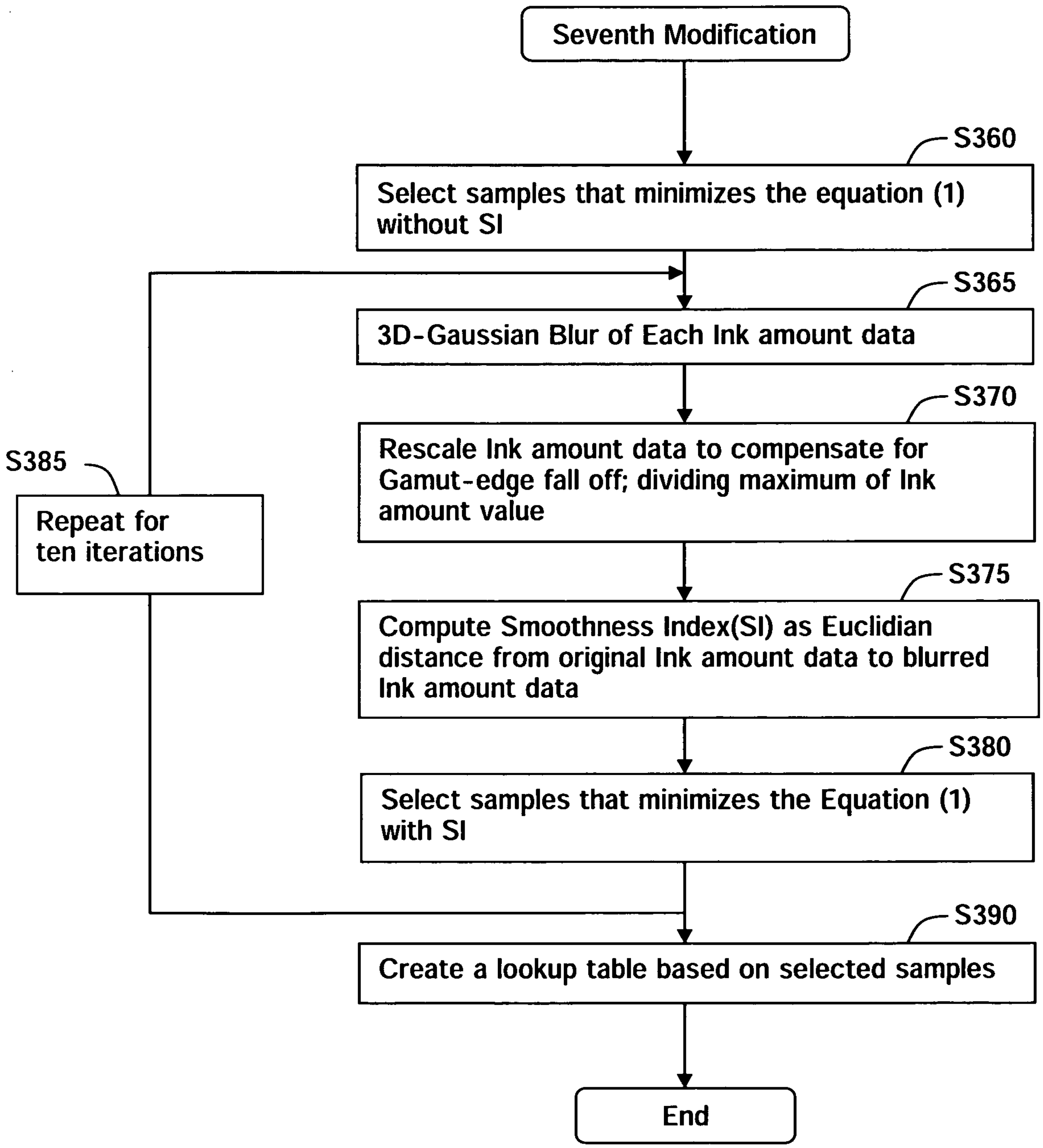

$\vec{La}_1$
$\vec{Lp}$
$\vec{La}_3$
$\vec{La}_6$
$\vec{La}_5$
$\vec{La}_4$
$\vec{La}_2$
$SI_3 = |(\vec{La}_1 - \vec{Lp}) + (\vec{La}_2 - \vec{Lp})| + |(\vec{La}_3 - \vec{Lp}) + (\vec{La}_4 - \vec{Lp})| + |(\vec{La}_5 - \vec{Lp}) + (\vec{La}_6 - \vec{Lp})|$
minimize
$\vec{La}_1$
$\vec{Lp'}$
$\vec{La}_3$
$\vec{La}_6$
$\vec{La}_5$
$\vec{La}_4$
$\vec{La}_2$

Fig.27



Seventh Modification
S360
Select samples that minimizes the equation (1) without SI
S365
3D-Gaussian Blur of Each Ink amount data
S370
Rescale Ink amount data to compensate for Gamut-edge fall off; dividing maximum of Ink amount value
S375
Compute Smoothness Index(SI) as Euclidian distance from original Ink amount data to blurred Ink amount data
S380
Select samples that minimizes the Equation (1) with SI
S385
Repeat for ten iterations
S390
Create a lookup table based on selected samples
End

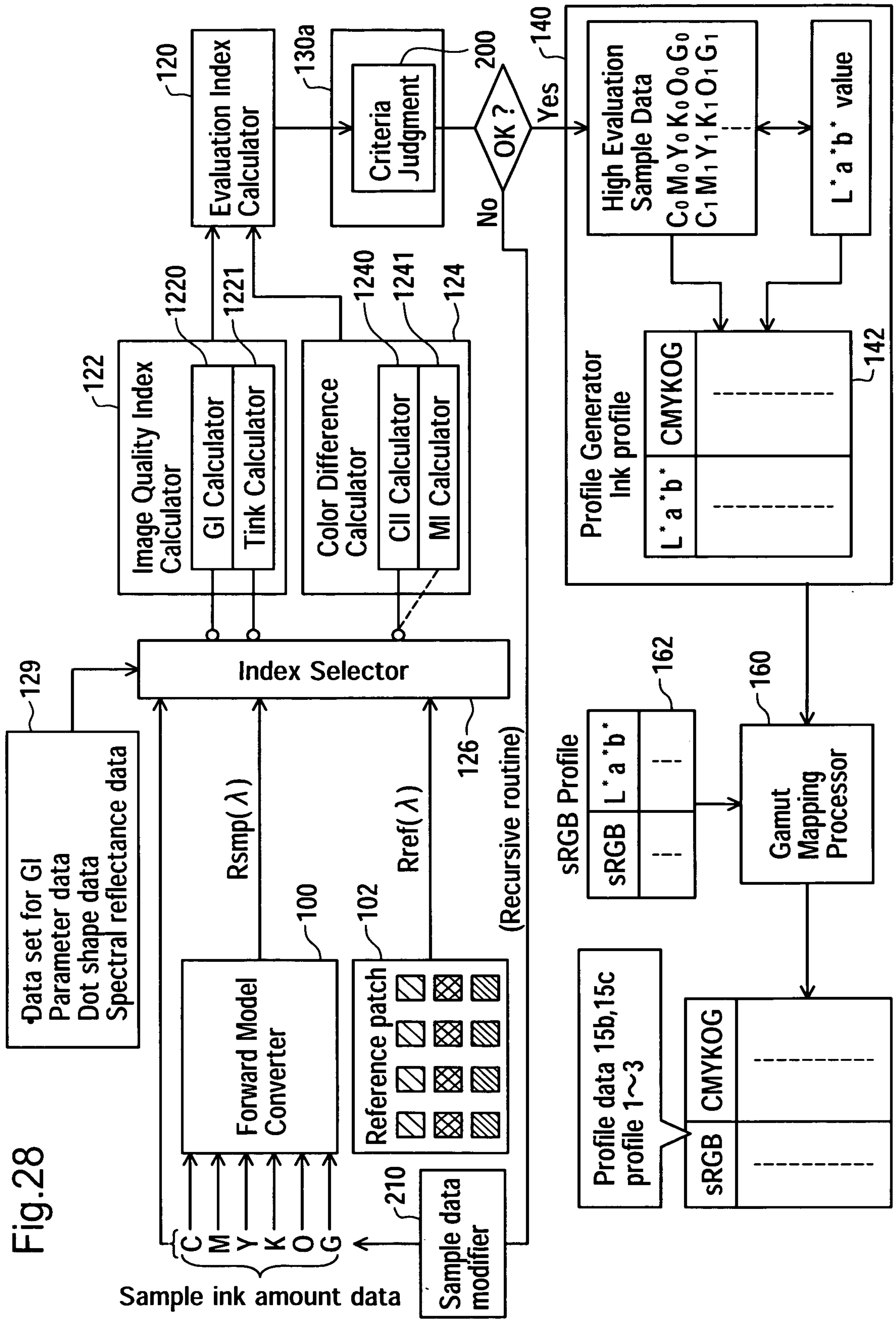

Data set for GI
Parameter data
Dot shape data
Spectral reflectance data
129
Index Selector
126
(Recursive routine)
Rsmp(λ)
Rref(λ)
Forward Model Converter
100
Reference patch
102
Sample data modifier
210
C
M
Y
K
O
G
Sample ink amount data
Image Quality Index Calculator
122
GI Calculator
Tink Calculator
1220
1221
Color Difference Calculator
124
CII Calculator
MI Calculator
1240
1241
Evaluation Index Calculator
120
Criteria Judgment
130a
200
OK ?
Yes
No
140
High Evaluation Sample Data
C0 M0 Y0 K0 O0 G0
C1 M1 Y1 K1 O1 G1
L*a*b* value
Profile Generator
Ink profile
L*a*b*
CMYKOG
142
sRGB Profile
sRGB
L*a*b*
162
Gamut Mapping Processor
160
Profile data 15b,15c
profile 1~3
sRGB
CMYKOG

Fig.28

Fig.29

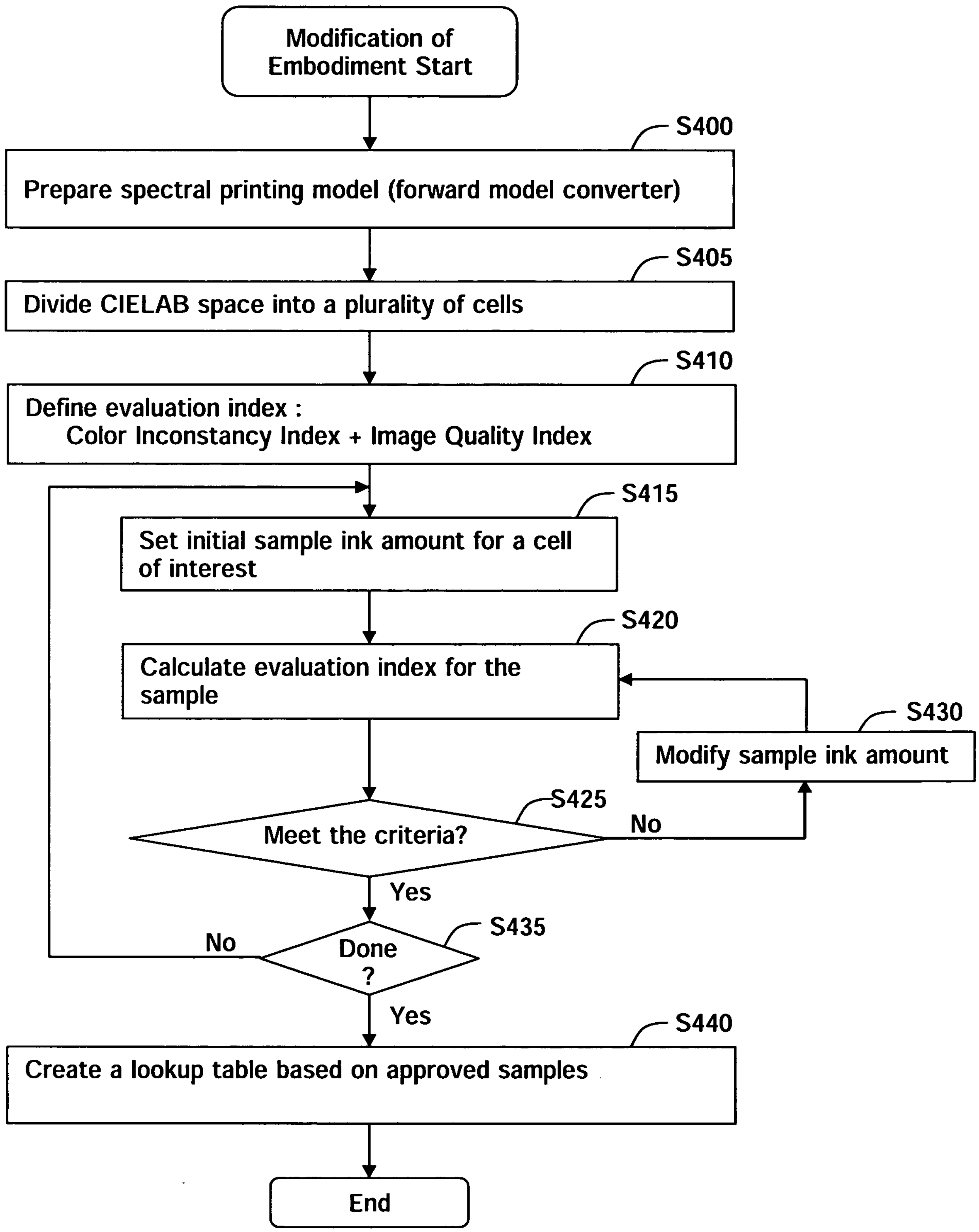

Modification of Embodiment Start
S400
Prepare spectral printing model (forward model converter)
S405
Divide CIELAB space into a plurality of cells
S410
Define evaluation index :
Color Inconstancy Index + Image Quality Index
S415
Set initial sample ink amount for a cell of interest
S420
Calculate evaluation index for the sample
S430
Modify sample ink amount
S425
Meet the criteria?
No
Yes
S435
Done ?
No
Yes
S440
Create a lookup table based on approved samples
End

Fig.30

dot position data (nozzle error)

		nozzle No				
		#1	#2	#3	------	#180
C	X	0	2	0	------	0
	Y	0	1	1	------	1
M	X					
	Y					
Y	X					
	Y					
K	X					
	Y					
O	X					
	Y					
G	X					
	Y					

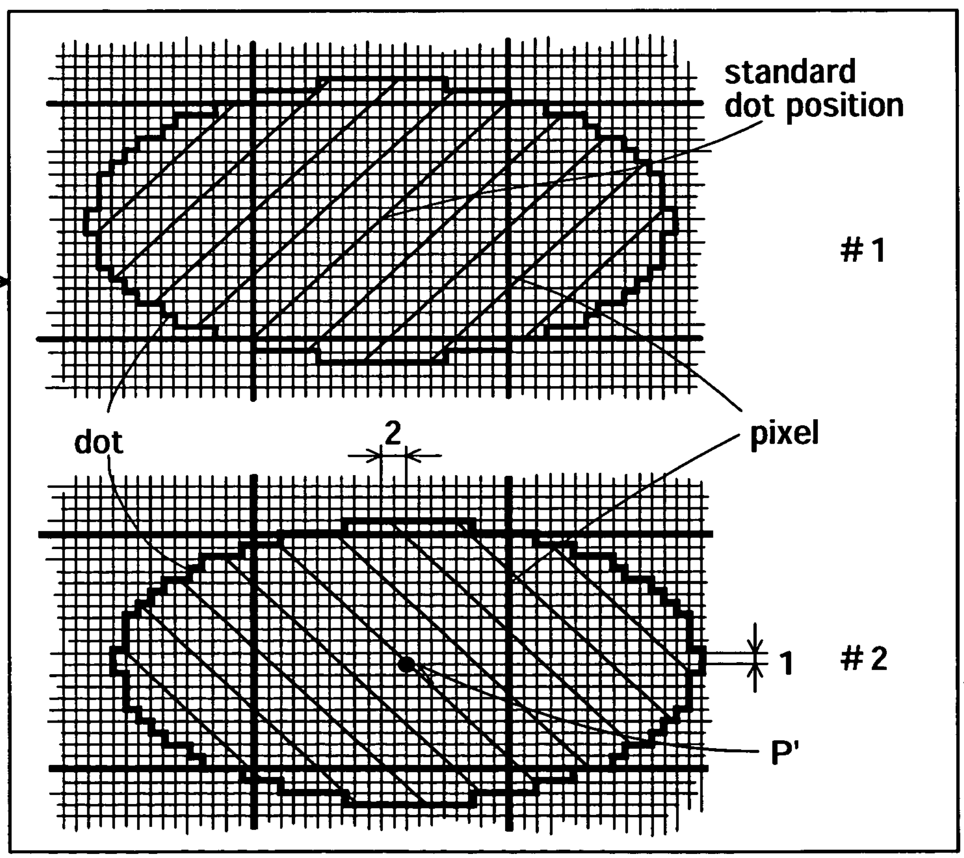
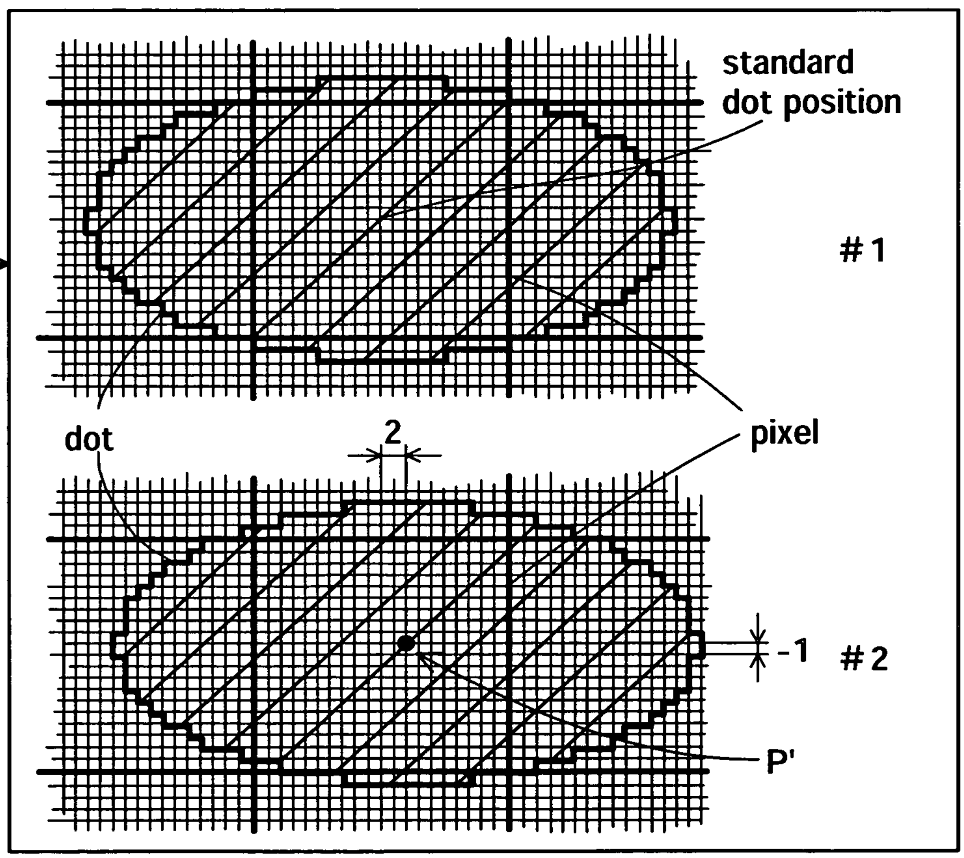


Fig.31

dot position data (feed error)

		path No				
		#1	#2	#3	----------	#N
C	X	0	2	0	----------	0
	Y	0	-1	-1	----------	1
M	X					
	Y					
Y	X					
	Y					
K	X					
	Y					
O	X					
	Y					
G	X					
	Y					



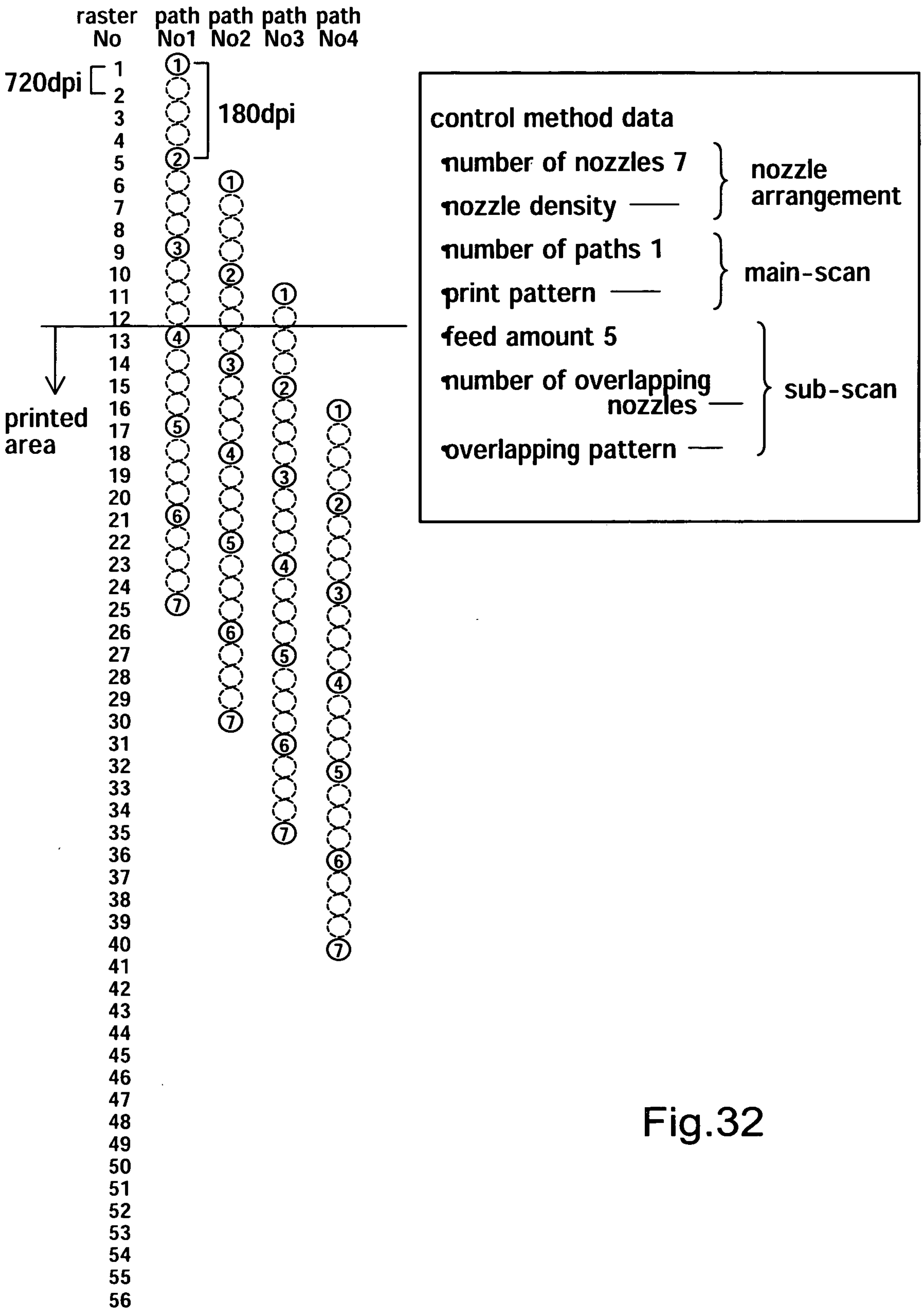

raster No
path No1
path No2
path No3
path No4
720dpi
180dpi
printed area
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
control method data
number of nozzles 7
nozzle density —
nozzle arrangement
number of paths 1
print pattern —
main-scan
feed amount 5
number of overlapping nozzles —
overlapping pattern —
sub-scan

Fig.32

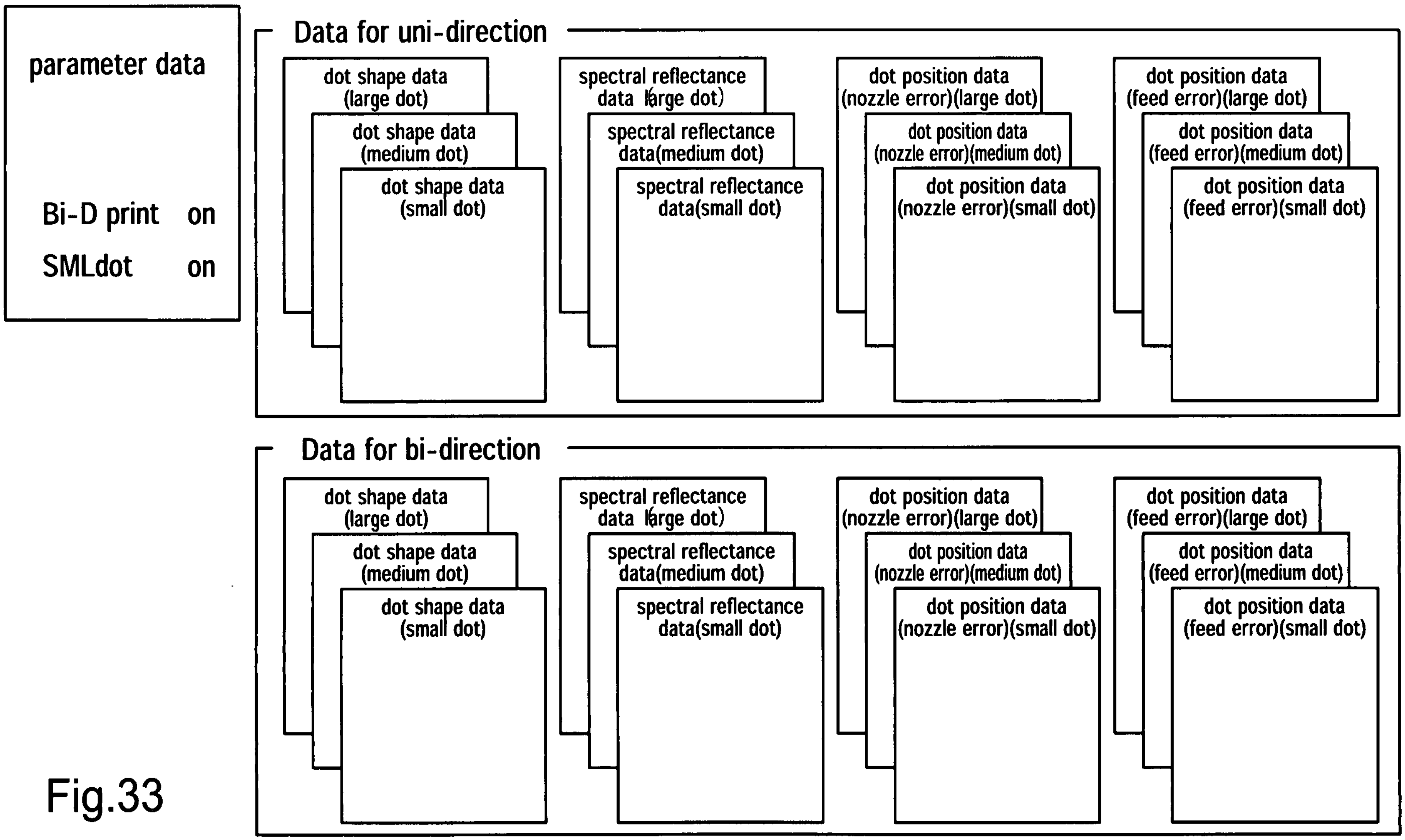
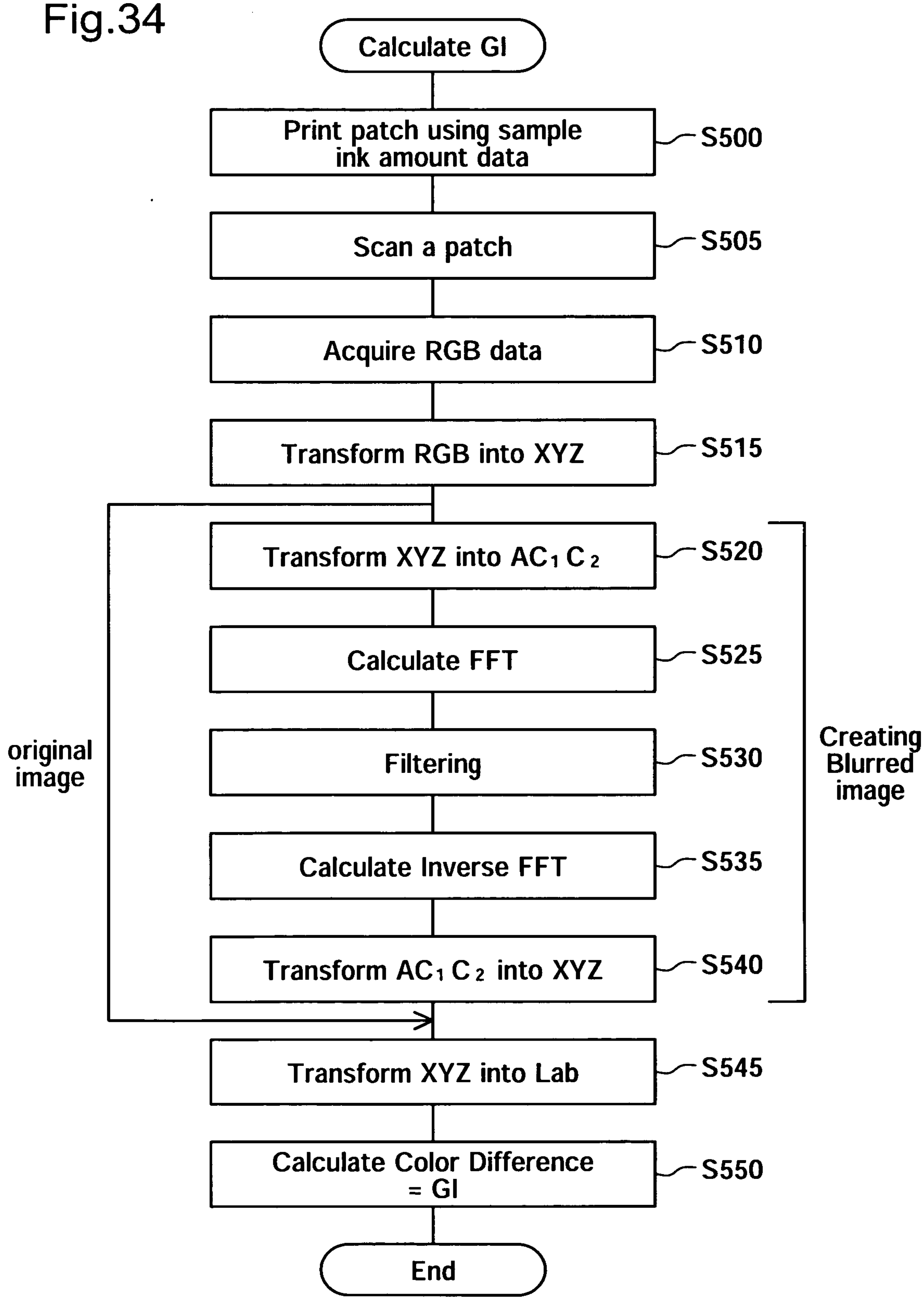

parameter data
Bi-D print on
SMLdot on
Data for uni-direction
dot shape data (large dot)
dot shape data (medium dot)
dot shape data (small dot)
spectral reflectance data (large dot)
spectral reflectance data(medium dot)
spectral reflectance data(small dot)
dot position data (nozzle error)(large dot)
dot position data (nozzle error)(medium dot)
dot position data (nozzle error)(small dot)
dot position data (feed error)(large dot)
dot position data (feed error)(medium dot)
dot position data (feed error)(small dot)
Data for bi-direction
dot shape data (large dot)
dot shape data (medium dot)
dot shape data (small dot)
spectral reflectance data (large dot)
spectral reflectance data(medium dot)
spectral reflectance data(small dot)
dot position data (nozzle error)(large dot)
dot position data (nozzle error)(medium dot)
dot position data (nozzle error)(small dot)
dot position data (feed error)(large dot)
dot position data (feed error)(medium dot)
dot position data (feed error)(small dot)

Fig.33

Fig.34



Calculate GI
Print patch using sample ink amount data
S500
Scan a patch
S505
Acquire RGB data
S510
Transform RGB into XYZ
S515
Transform XYZ into AC1 C2
S520
Calculate FFT
S525
Filtering
S530
Calculate Inverse FFT
S535
Transform AC1 C2 into XYZ
S540
Transform XYZ into Lab
S545
Calculate Color Difference = GI
S550
End
original image
Creating Blurred image